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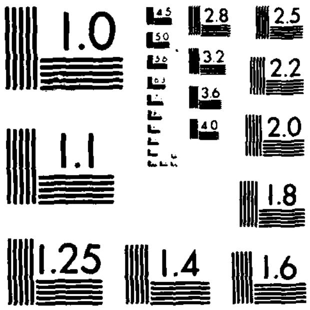

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Technical Report E-84-5	2. GOVT ACCESSION NO. AD-A142 794	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) INVESTIGATION OF WATER QUALITY AND PLANKTON IN SELECTED AQUATIC HABITATS ON THE LOWER MISSISSIPPI RIVER		5. TYPE OF REPORT & PERIOD COVERED Final report 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Bruce M. Sabol Linda E. Winfield David G. Toczydlowski		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS U. S. Army Engineer Waterways Experiment Station Environmental Laboratory P. O. Box 631, Vicksburg, Miss. 39180		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS EWQOS Work Unit VIIB
11. CONTROLLING OFFICE NAME AND ADDRESS Office, Chief of Engineers, U. S. Army Washington, D. C. 20314		12. REPORT DATE April 1984 13. NUMBER OF PAGES 97
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Available from National Technical Information Service, 5285 Port Royal Road, Springfield, Va. 22161.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Aquatic biology (LC)
Habitats (WES)
Mississippi River (LC)
Plankton (LC)
Water quality--Lower Mississippi River (LC)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Water quality and plankton samples were collected monthly at selected stations in the main channel, a dike field, an abandoned channel, and a secondary channel in the Lower Mississippi River near Greenville, Miss., from November 1979 to September 1980, and in additional dike fields during a low water period in September 1980.

The main channel was characterized by high current velocities, high

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20. ABSTRACT (Continued).

suspended solids, low light penetration, relatively high nutrient concentrations, generally low chlorophyll and zooplankton concentrations, stable and slightly alkaline pH levels, and stable oxygen saturation (~90 percent). Detrital particulate organic matter (POM) comprised over 80 percent of the total POM for all sampling periods except August when algal POM comprised over half the total.

The abandoned channel was characterized by quiescent, generally stratified eutrophic waters low in suspended solids and high in chlorophyll and zooplankton concentrations with moderately fluctuating pH levels and widely fluctuating oxygen saturation levels.

Water quality and plankton conditions observed in the secondary channel were indistinguishable from the main channel during periods of flow. During quiescent periods, suspended solids and turbidity decreased although other variables showed no appreciable difference from the main channel.

Dike fields were transient lentic environments. During lotic periods, water quality was indistinguishable from the main channel. During isolation from the main channel, water clarity increased, soluble nutrients decreased, chlorophyll and zooplankton concentrations increased, and high pH and oxygen saturation levels were often observed. During the long period of isolation from the main channel, the dike fields became increasingly different from the main channel and from one another.

PREFACE

The study described in this report was sponsored by the Office, Chief of Engineers (OCE), U. S. Army, under the Environmental and Water Quality Operational Studies (EWQOS) Program, Work Unit VIIB, Waterways Field Studies. The EWQOS Program has been assigned to the U. S. Army Engineer Waterways Experiment Station (WES) under the direction of the Environmental Laboratory (EL). The OCE Technical Monitors for EWQOS were Mr. Earl Eiker, Mr. John Bushman, and Mr. James L. Gottesman.

This report presents results of a study designed to document plankton and water quality conditions associated with selected different types of habitat found within the main-line levees along the Lower Mississippi River. Plankton and water quality samples were taken from the river between miles 504 and 566 during November 1979 through September 1980.

The report was prepared by Mr. Bruce M. Sabol, Mrs. Linda E. Winfield, and Mr. David G. Toczydlowski under the supervision of Dr. Thomas D. Wright, Chief, Aquatic Habitat Group (AHG), and Mr. Bob O. Benn, Chief, Environmental Systems Division. Dr. Jerome L. Mahloch was Program Manager, EWQOS; and Dr. John Harrison was Chief, EL.

Special appreciation is expressed to Mr. Eugene G. Buglewicz, formerly of AHG, for assistance during the planning phase of this study; to Mr. Larry G. Sanders, AHG, for field support; to SP-5 V. Brown, AHG, for laboratory assistance; and to Dr. Michael P. Farrell, Oak Ridge National Laboratory, for data analysis support.

Commanders and Directors of WES during the study and the preparation of this report were COL Nelson P. Conover, CE, and COL Tilford C. Creel, CE. Technical Director was Mr. Fred R. Brown.

This report should be cited as follows:

Sabol, B. M., Winfield, L. E., and Toczydlowski, D. G. 1984. "Investigation of Water Quality and Plankton in Selected Aquatic Habitats on the Lower Mississippi River," Technical Report E-84-5, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

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CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
feet	0.3048	metres
miles (U. S. statute)	1.609347	kilometres

INVESTIGATION OF WATER QUALITY AND PLANKTON IN SELECTED AQUATIC HABITATS ON THE LOWER MISSISSIPPI RIVER

PART I: INTRODUCTION

Background

1. The basic purpose of the Environmental and Water Quality Operational Studies (EWQOS) Program is to provide new or improved technology for the planning, design, construction, and operation of Corps of Engineers (CE) projects in an effort to solve selected environmental quality problems. A key element of EWQOS is the use of field studies to evaluate and document environmental quality conditions associated with CE projects.

2. One major problem area identified by CE field offices as being of high priority was the environmental impacts of project activities on waterways (Keeley et al. 1978). Specifically, it was determined that EWQOS research should develop field office guidance to address environmental features of dikes. Such structures are found in waterways in many parts of the United States and are very common along the Mississippi River and its tributaries. This work was specifically conducted to document the effects dikes have on plankton and water quality conditions.

Dikes

3. The principal purposes of dikes are to adjust main channel width, depth, and alignment, and to close secondary channels. This is accomplished by reducing the river cross-sectional area, resulting in increased flow (scouring and deepening) through one portion of the channel and decreased flow (sedimentation) in the other portion. Dikes are probably the most effective means of channel alignment and contraction in use today.

4. Dikes are constructed of permeable wooden piles (permeable dikes) or, more typically in present times, of relatively impermeable stone riprap (impermeable dikes). Dikes may be singular or placed one after another along a bank forming a dike field. Generally, dikes in the Lower Mississippi River are of the transverse type which extend from the bank perpendicular to the current. An extension, or L-head, may be placed at the offshore end of a dike parallel to the current to retard scouring and turbulence. Vane dikes, which are placed in the channel parallel or oblique to the current, are also used.

5. Water is shunted by a dike toward the opposite riverbank; if this bank is stable, the resulting narrower channel is deepened by scouring. Dikes are typically placed on the convex side, or point bar, in a bendway, or in straight reaches to reduce channel sinuosity. Suspended sediments are deposited downstream of individual dikes due to the reduction of current velocities caused by the structure. In dike fields, sediment accretion may be appreciable, and these accumulated sediments, which may in some instances form a bar, further serve to confine the flow of water. Slack water pools may be found downstream of transverse dikes at low river stages in cases where sediment accretion has not completely filled these areas.

6. As of 30 September 1980, there were over 400 dikes on the Lower Mississippi River having a combined length of 296 km. The number of dikes diminishes downstream in the Lower Mississippi River, with no dikes being present in the river within the confines of the New Orleans District. However, many new structures are planned within the next two decades in the lower river.

7. Ecologically, slack waters are known to be important in river systems. These areas add physical diversity to the overall river system and serve in a number of ecological capacities. First, these lentic areas are known to be a principal contributor of plankton in most river systems (Blum 1956, Hynes 1972). Differing abundance, species composition, and functional types of benthic invertebrates are produced in lentic and lotic environments (Hynes 1972); therefore, a river system containing both lentic and lotic habitats would have a greater overall

diversity of benthic macroinvertebrates. Fish communities in river reaches devoid of slack-water areas have been shown to be less diverse than in reaches containing slack-water areas (Kallemeyn and Novotny 1977). Slack-water areas are important for spawning and nursing functions of fishes (Kallemeyn and Novotny 1977, Ragland 1974).

8. Dikes serve to create transient slack-water habitats during certain river stages. However, at the initiation of this study, no studies had been published which documented the ecological effects of dikes or determined how these areas compared with "natural" slack-water areas. Various specific ecological topics need to be addressed with research:

a. Determination of the relative importance of plankton and macroinvertebrate production within dike fields.

b. Determination of water quality changes in dike fields following isolation from the river and an assessment of whether these conditions become detrimental to aquatic life.

c. Assessment of the actual use of dike fields by fish for feeding and spawning, and as nursery areas for fry.

9. As part of the EWQOS Waterways Field Studies, research was conducted to address these questions and to determine the ecological importance of the habitats created by dike fields as compared with "natural" riverine habitats. The present report addresses only water quality and plankton; benthic invertebrate studies are described by Beckett et al. (1983); larval fish studies are described by Connor, Pennington, and Bosley (1983); and fisheries studies are described by Pennington, Baker, and Bond (1983).

Objectives

10. There were three primary objectives of this study. The first was to quantitatively describe and compare physical, chemical, and biological conditions in selected habitats, including a dike field, the main channel, an abandoned channel, and a secondary channel. Variables examined in this study were those deemed ecologically significant

(Table 1), i.e., important to or indicative of aquatic life.

11. The second objective was to develop hypotheses on how dike fields may affect water quality.

12. The third objective was to develop recommendations on improved experimental design, and analytic and interpretive techniques for conducting environmental water quality studies on habitats in large river systems.

PART II: STUDY AREA

General Description

13. The study area encompassed a 100-km reach of the Lower Mississippi River (Figure 1) near Greenville, Miss. (river miles 504 to 566). The study area is confined on both sides by main-line levees constructed by the CE for flood-control purposes. Leveed floodplain width ranges from 3 to 10 km. Backwater habitats between the levees and the main river channel have indirect or seasonal connections with the river and are often submerged during floods. There are no tributaries entering the river within the study area.

14. Average discharge of the river at Vicksburg, Miss.,* is about 15,900 m^3/sec. Recorded discharges have ranged from about 2,800 m^3/sec at extreme low river stage to 76,500 m^3/sec at high stages, with an 18-m difference in water level. The average water velocity within the main channel is from 90 to 180 cm/sec with a maximum recorded velocity of 460 cm/sec during extremely high flows. The average hydrograph for the river at Vicksburg shows highest discharges occurring from February through March and lowest discharges occurring from July through October. The estimated average bed-load transport at Vicksburg is 760,000 m^3/day.

15. The climate and physiography of the study area and the navigation and flood-control objectives for the Lower Mississippi River are described in detail by Miller (1981).

Habitats Sampled

16. The general study area was divided into various distinct habitat types; the four habitat types selected for detailed examination in this study are described in the following paragraphs.

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* A major gaging and data collection point for the Lower Mississippi River located 105 km downstream from the study area.

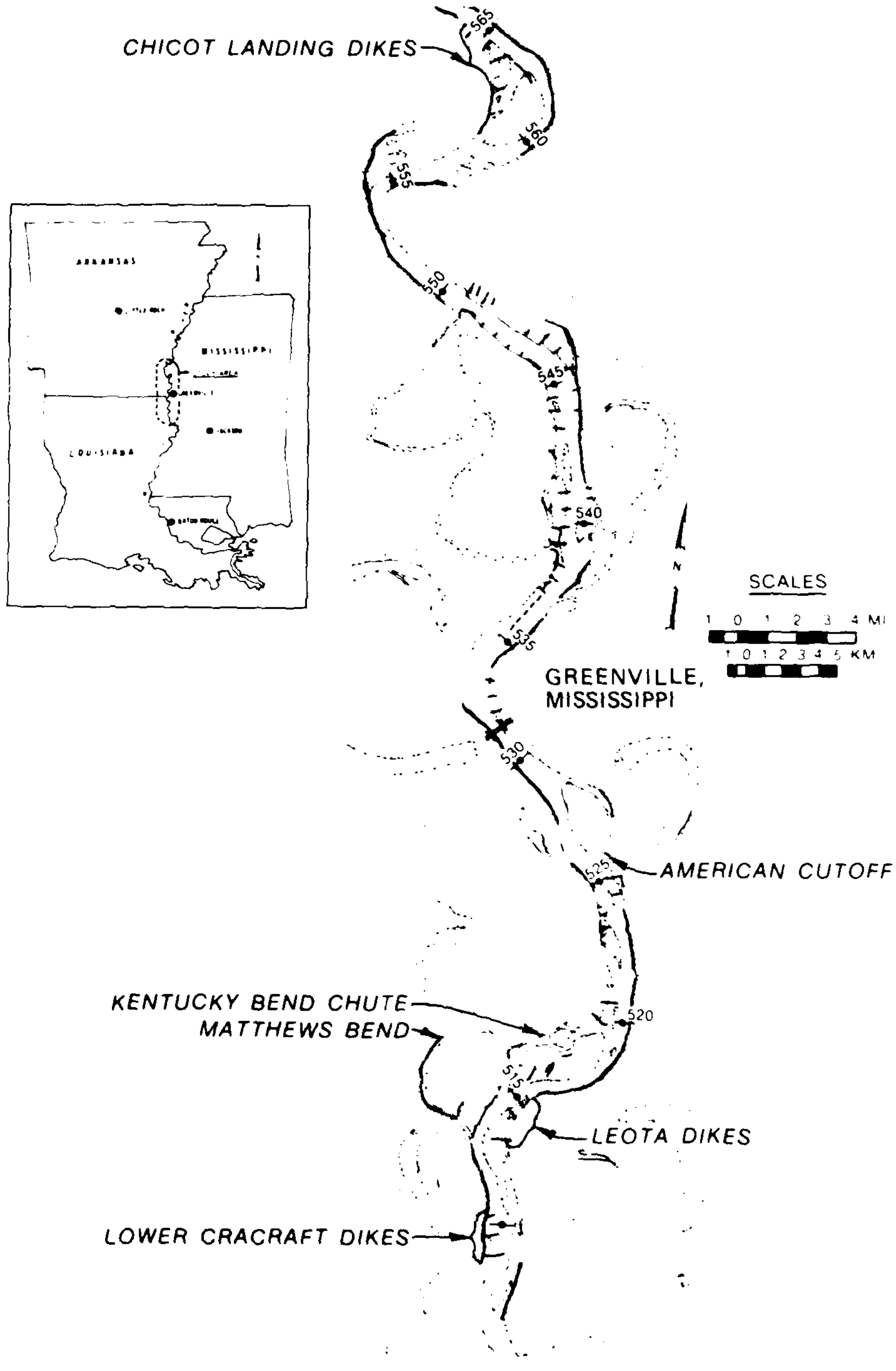


Figure 1. Study area

Main channel

17. The main channel habitat (MC) includes the thalweg line and on either side up to the 3-m low water reference plane (LWRP). Sample sites in this habitat are characterized by deep, turbid, fast-moving water. The bottom is well scoured, consisting of coarse sand and gravel.

Dike fields

18. Dike field habitat is defined as the area influenced directly by a dike or series of dikes. Dikes are usually placed no lower than -10 ft* LWRP. At high flows the current is swift and the water can inundate the dike by 6 to 9 m. At low discharge the dikes are as much as 3 to 4 m above water level. A total of 60 dikes in 15 dike fields are in place in the study area. Transverse dikes, permeable and impermeable, are the predominant types although there are a few vane dikes and a single L-head dike in the area. Three dike fields, Lower Cracraft, Leota, and Chicot Landing, were selected for study.

19. Lower Cracraft Dike Field (DFC) (river miles 506.5-511.0). This dike field (Figure 2), constructed in 1971-72, consists of three transverse stone dikes constructed for the dual purpose of secondary channel closure and point bar stabilization. Extensive sand and gravel middle bars occur between succeeding dikes and over a 4.8-km reach of river downstream from the third dike. These middle bars, the main axis of which is parallel to the main channel, isolate extensive pools from main channel flow during low river discharge periods, and confine the dike field pools between the dikes, the river bank, and the middle bars. Plunge pools that are deep relative to the remaining pools exist downstream of each dike. The pool below dike 3 (furthest downstream dike) is deep along its entire length relative to the other two pools. Isolated areas of willow trees occur on the middle bar. Substrate type within the pools varies from mud to coarse sand and gravel depending upon river stage.

20. Leota Dike Field (DFL) (river miles 511.5-515.5). This dike

* A table of factors for converting U. S. customary units of measurement to metric (SI) is presented on page 4.

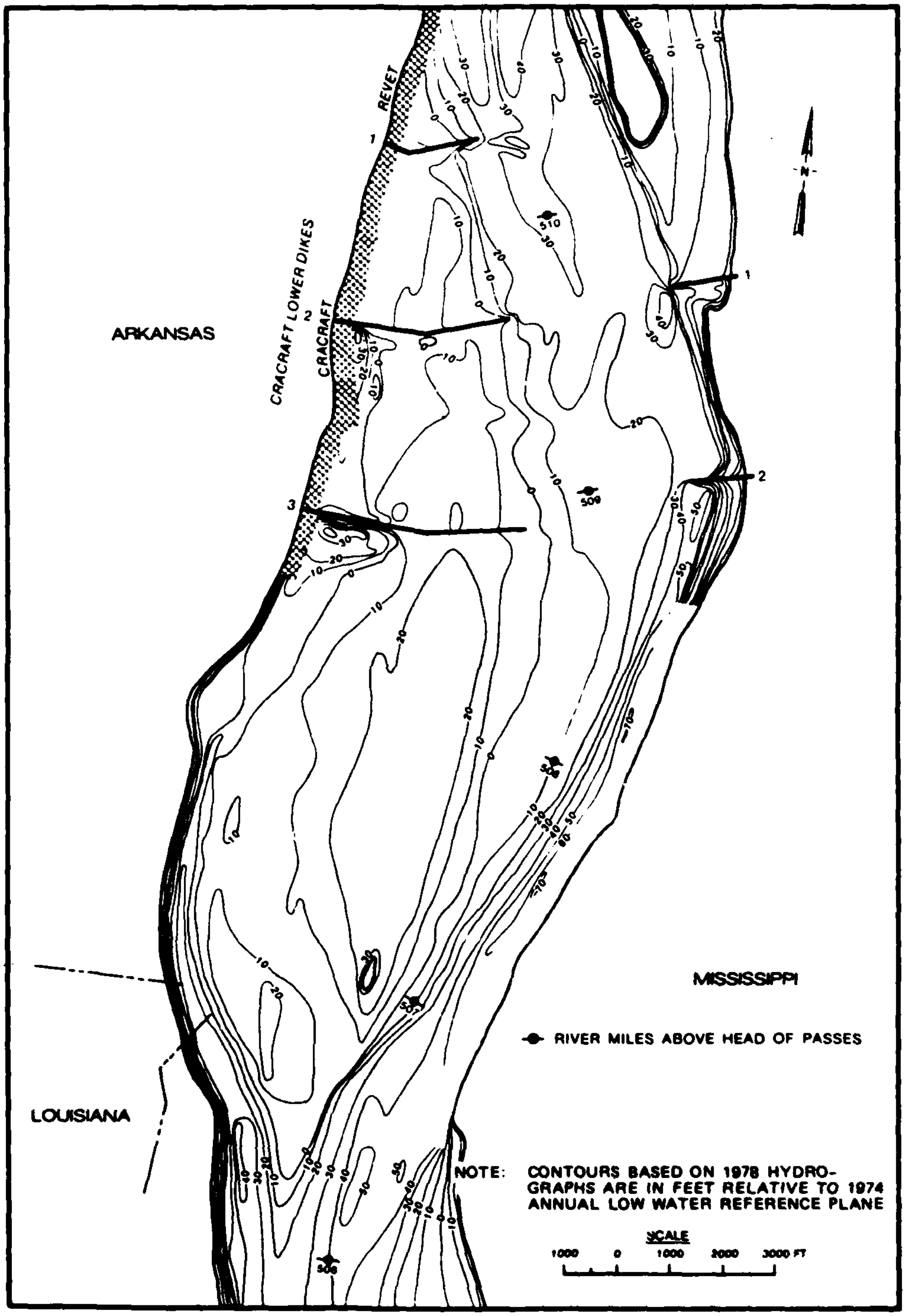


Figure 2. Lower Cracraft Dike Field

field (Figure 3) consists of three transverse stone dikes built in 1968 for the dual purpose of secondary channel closure and point bar stabilization. An extensive sand and gravel middle bar extends downstream from dike 1 to approximately 2.4 km below dike 3. Extreme sedimentation downstream of each dike has resulted in shallow water with mostly sand and gravel overlain with mud and silt at low river stages. There are no large plunge pools behind the dikes in this dike field. Isolated areas of vegetation, primarily small willows and cottonwood trees, occur on the middle bar.

21. Chicot Landing Dike Field (DFT) (river miles 562.0-565.5). This dike field (Figure 4) was constructed in 1967-1969 to divert secondary channel flow from behind Choctaw Bar. The original structure consisted of three transverse stone dikes and a series of three vane dikes downstream from the last transverse dike. Since original construction, the third transverse dike has suffered a breach failure. In 1975 the vane dikes were connected to the third dike and extended downstream so that the third dike is now a large L-head dike with a notch in the upstream leg of the L (Figure 4). The area of the dike field above the first dike is almost entirely silted in. The pools below dikes 1 and 2 exhibit very little or no flow at low water stages. They are separated from the main channel by a sandbar at all but the lower end of pool 2. The secondary channel below dike 3 (pool 3) is separated from the main channel by the long leg of the L-head dike and the Choctaw Bar Island. Because pool 3 resembles a secondary channel, it is analyzed as a separate habitat from the upper two pools.

Secondary channels

22. This aquatic habitat is found where flow in the main channel is divided by a middle island or bar. The secondary channel is the smaller channel and is subordinate in the flow-carrying capacity to the main channel. Two secondary channels were sampled during this study. The first, American Cutoff (PCA) (Figure 5), is located between river miles 525.2 and 528.3. This is a permanent channel and flow occurs year-round in this habitat. The second, Kentucky Bend Chute (TCK) (Figure 6), is located between river miles 515.0 and 519.0. This is a

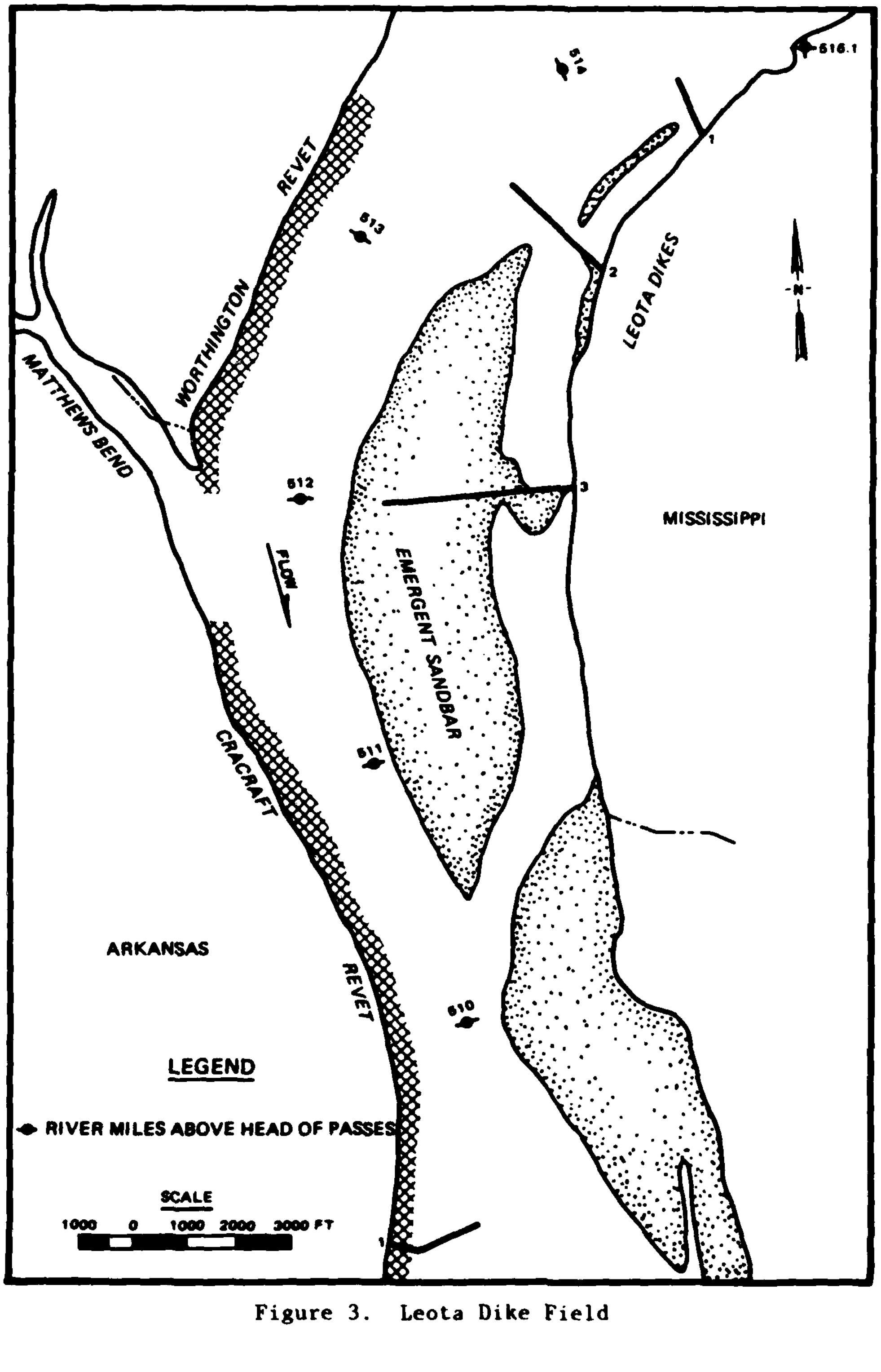


Figure 3. Leota Dike Field

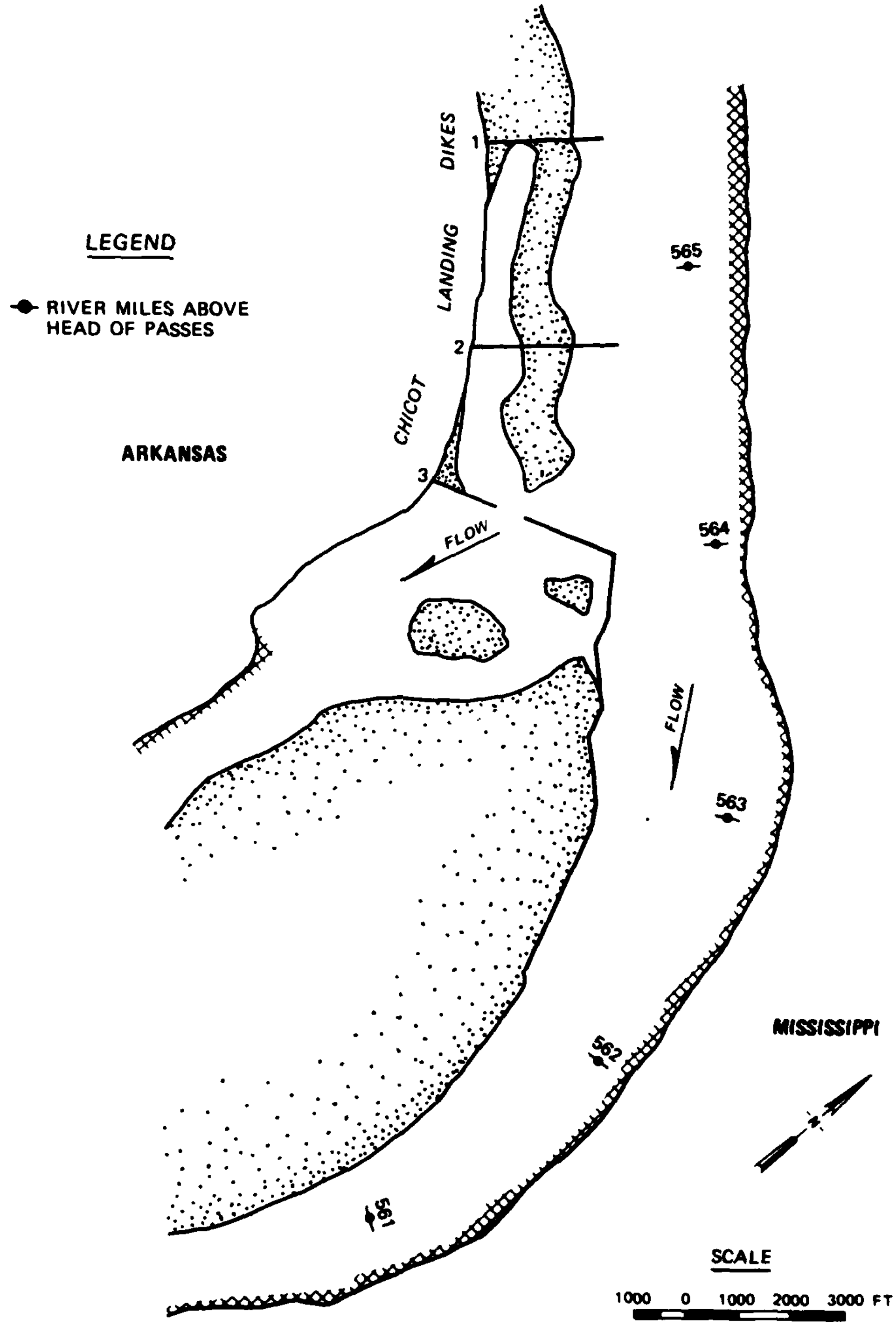


Figure 4. Chicot Landing Dike Field

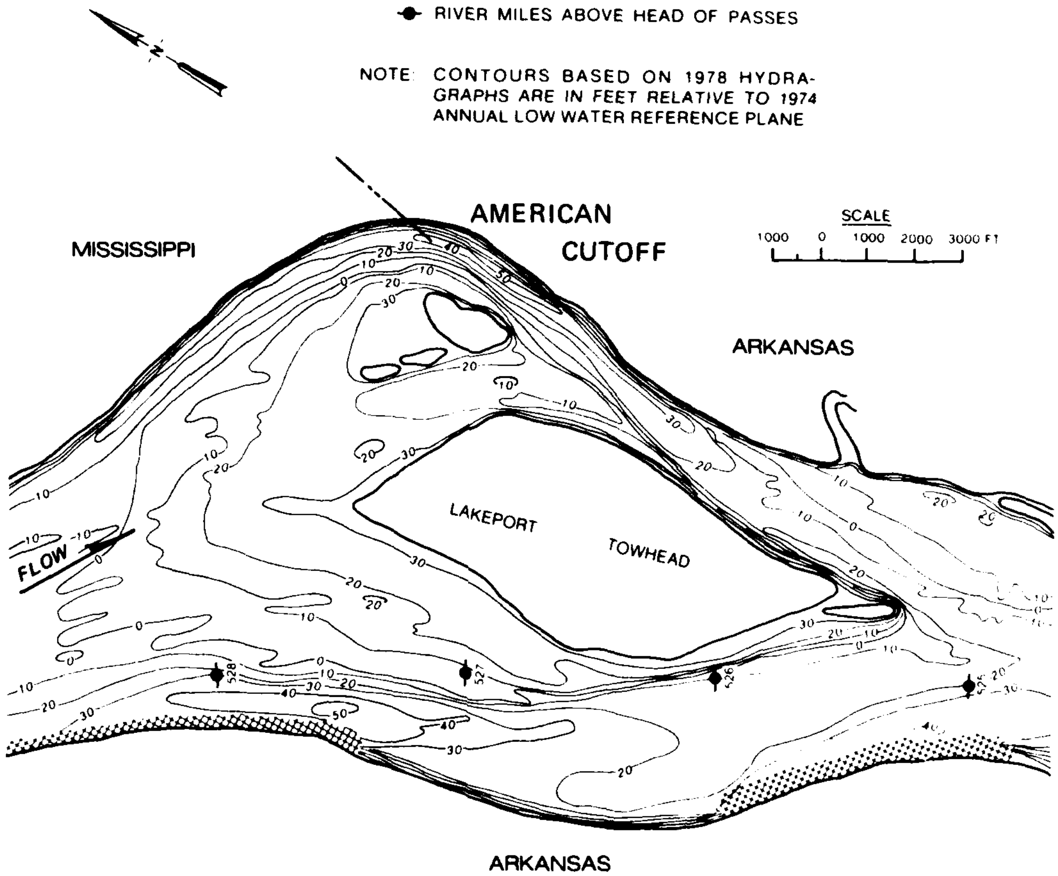


Figure 5. American Cutoff, permanent secondary channel

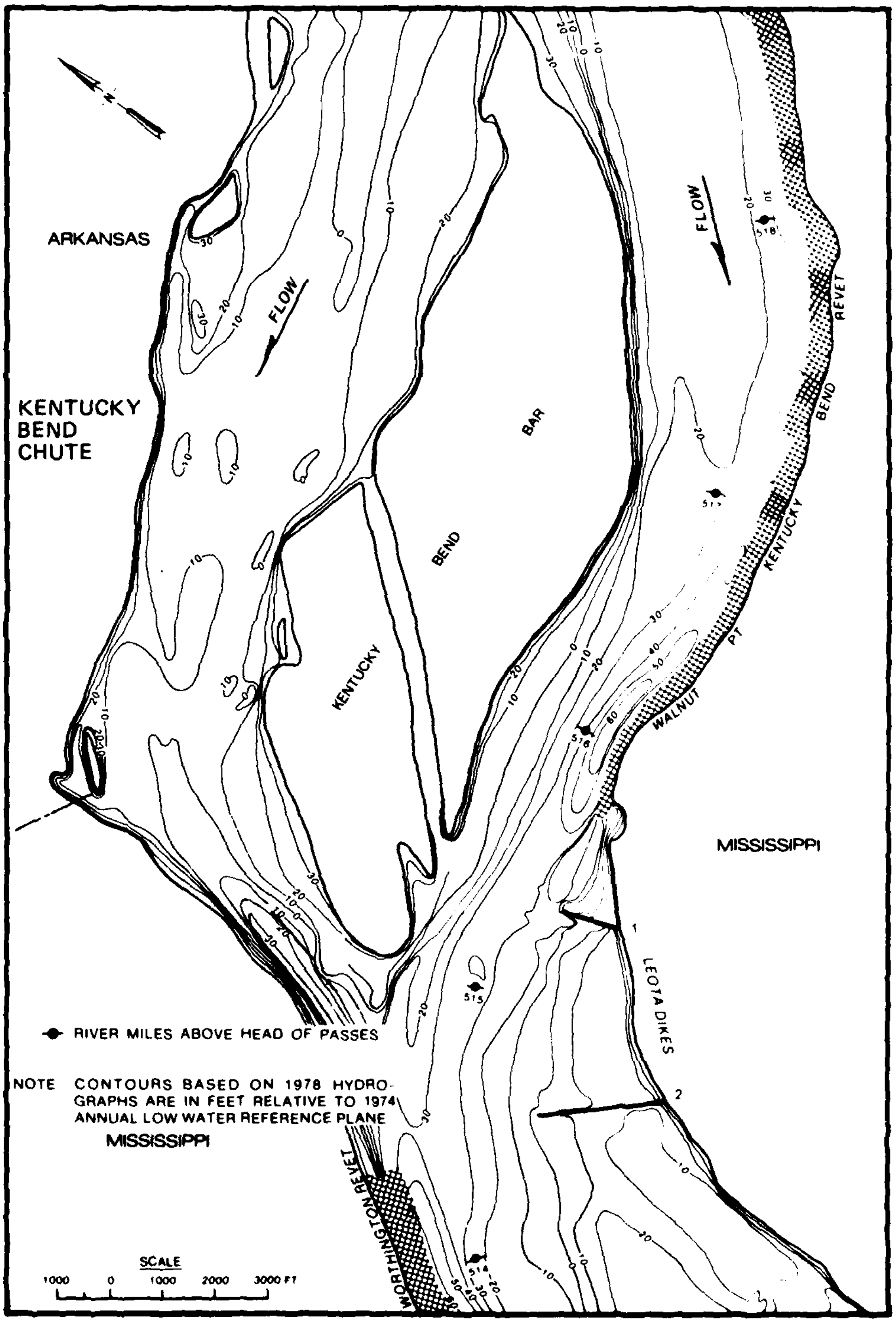


Figure 6. Kentucky Bend Chute, temporary secondary channel

temporary channel and flow only occurs in this habitat at river stages above 21.5 ft on the Greenville gauge.

Abandoned river channels

23. This habitat consists of relatively small, old river channels formed by natural or man-made bendway cutoffs or other meandering action of the river. Abandoned channels are distinguished from oxbow lakes primarily by their much smaller size. However, it is recognized that both habitat types are formed by similar river action and are old river courses. This habitat remains confluent with the main channel by an outlet channel throughout most if not all of the year. Lentic conditions exist in abandoned channels except when inundated during periods of overbank flow. Sediments are a flocculent silt-clay that may contain large amounts of detritus in the form of leaves or twigs. Water clarity is high compared to the turbid conditions of the main channel.

24. An abandoned river channel, Matthews Bend (ACB), was sampled during this study. Matthews Bend is contiguous with the river at river mile 513.0 (Figure 7). Measured at low water from its confluence with the main channel to its head, Matthews Bend is approximately 8 km long with depth decreasing in the upstream direction. At high flow, some water from the river enters upstream and moves through the channel creating a slight current. At moderate and low flows, however, the entire area is a backwater.

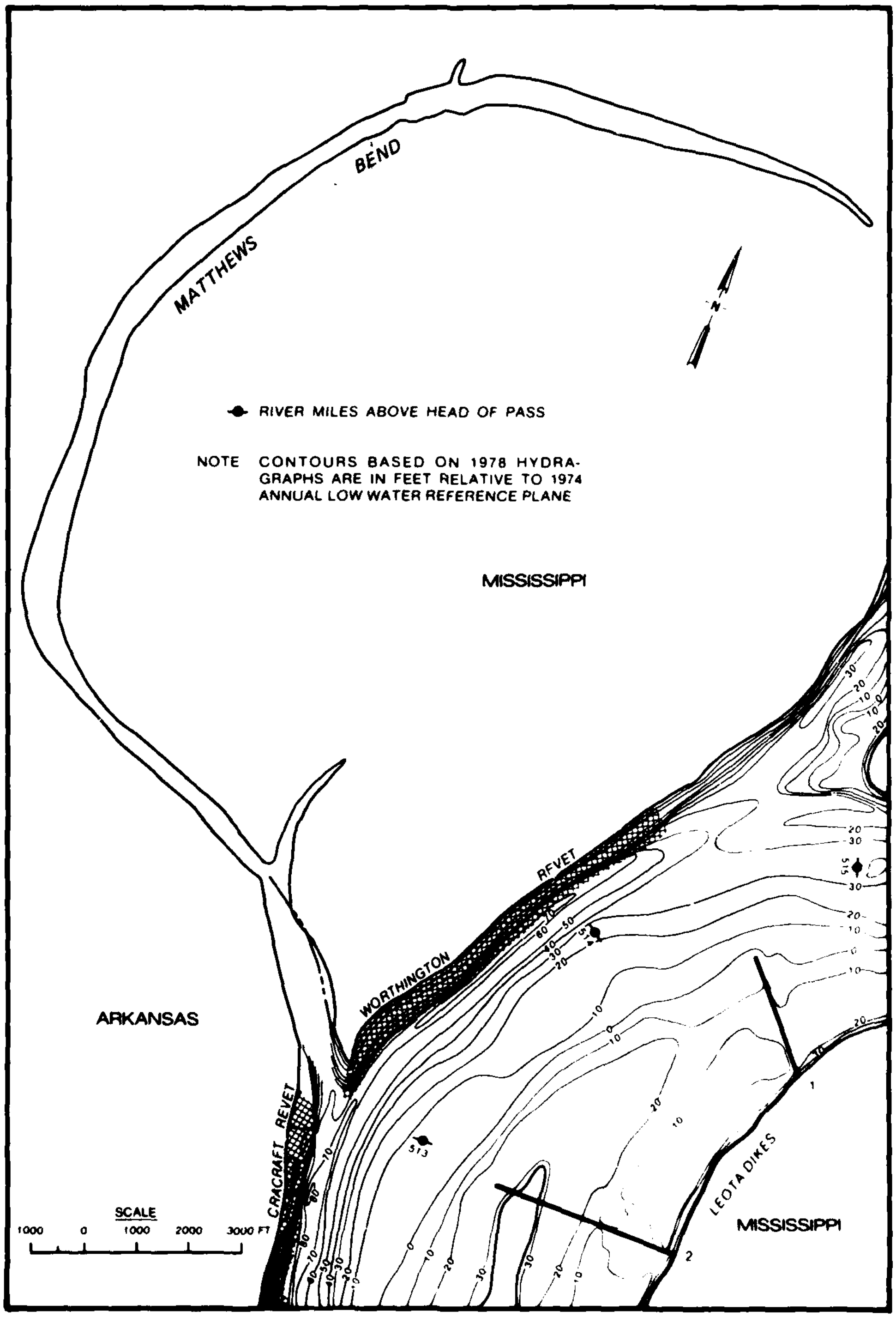


Figure 7. Matthews Bend, abandoned channel

PART III: METHODS

Sampling Design and Rationale

25. Field sampling was conducted in two phases. First, a monthly study was performed and consisted of monthly sampling (November 1979-September 1980) of one or two fixed point stations in four habitats within a small section of the study area. The purpose of this sampling was to examine water quality conditions at several representative stations in selected habitats over a wide range of temperature and flow conditions. The second phase was a low water study consisting of one-time, spatially intensive sampling conducted in additional selected habitats over the entire study area during a low water period in September 1980. The purpose of this sampling was to compare habitats during a time when overall riverine spatial variability was expected to be greatest.

26. Variables examined in this study were deemed ecologically significant, i.e., important to or indicative of aquatic life. These included the following:

- a. Physical variables. Current velocity, temperature, water transparency, suspended solids load, and specific conductance.
- b. Chemical variables. Dissolved solids, alkalinity, pH, free-carbon dioxide, dissolved oxygen, oxidation-reduction potential, and algal macronutrients including nitrite-nitrate nitrogen, ammonia nitrogen, total phosphorus, and dissolved orthophosphate.
- c. Biological variables. Photosynthetic pigment (indicative of algal density), zooplankton density and composition, and particulate and dissolved organic matter.

Particular emphasis was placed on: (a) determining the occurrence and extent of conditions adverse to aquatic life, such as deoxygenation; and (b) defining the quantity and quality of particulate organic matter (POM) within habitats since POM is the basic energy source and thus changes in quantity and quality of POM between habitats may help determine how a habitat functions in ecological terms. These variables are

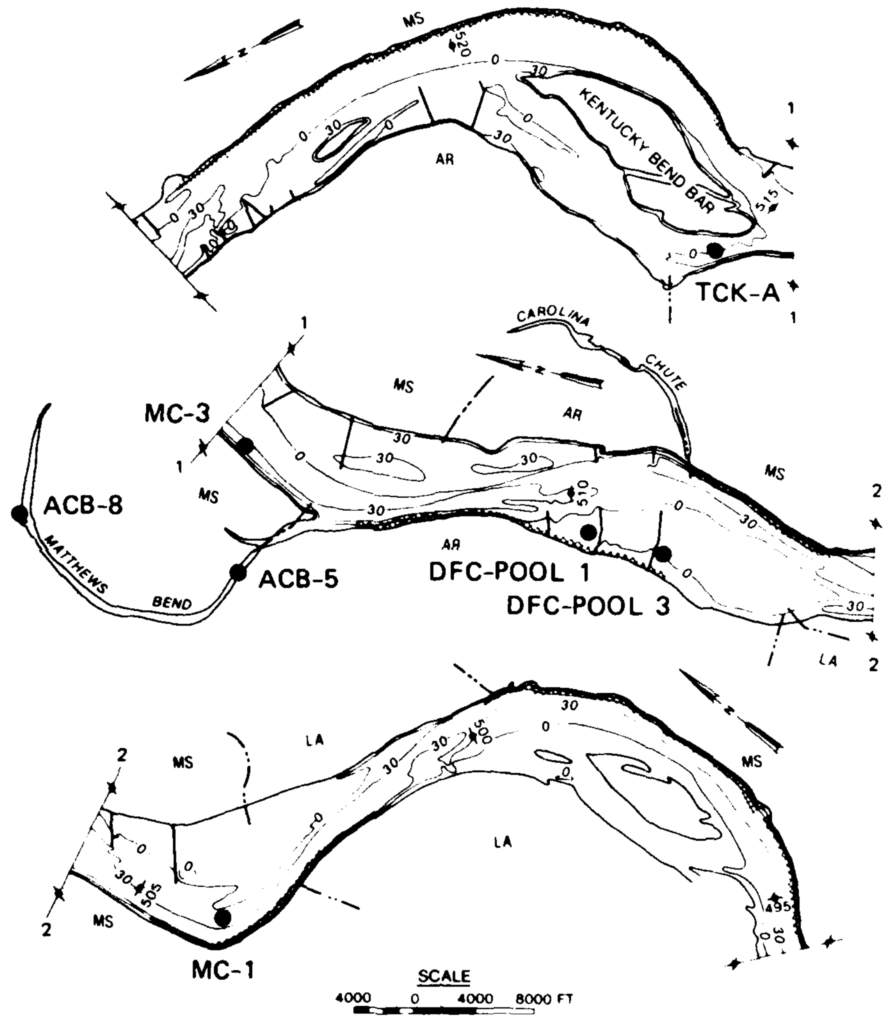
listed in Table 1. The general working hypothesis was that conditions were thought to differ between habitats in response to different current regimes.

Monthly study

27. Seven stations in four habitats (Figure 8) including the main channel, Matthews Bend, Kentucky Bend Chute, and Lower Cracraft Dike Field were sampled every 3 to 5 weeks, weather permitting, without specific regard to river stage (Figure 9). Two main channel stations were selected, one above the confluence of Matthews Bend (MC-3) and one below the Lower Cracraft Dike Field (MC-1). Both stations were located on the outside of bends, approximately 100 m offshore of the riverbank revetment. This made it possible to sample high velocity main channel river water without being in the path of towboat traffic. Two stations in the Lower Cracraft Dike Field were sampled, one in the first pool just upstream of the second dike (DFC pool 1) and the other in the third pool just downstream of the third dike (DFC pool 3). DFC pool 1 was frequently lentic whereas DFC pool 3 was more frequently lotic, with water entering the dike field across a low point in the sandbar adjoining the second pool. Two stations in Matthews Bend were sampled, one (ACB-5) in midchannel 2.3 km from the confluence with the river and the other (ACB-8) in midchannel 6.4 km from the river confluence. A single station was sampled in Kentucky Bend Chute (TCK-A), in midchannel 1.1 km upstream from the downstream confluence with the river.

28. These stations were selected because they were judged to be typical of the habitat in which they were located and because it was thought they would be easily accessible throughout the year. During the August sampling, however, the water level was sufficiently low to make the DFC pool 1 station inaccessible with the sampling boat used; therefore, this station was missed from this sampling.

29. During each monthly sampling the order of sampling was varied such that no station was sampled at the same time of day as was done the previous month, and stations in the same habitat were not sampled consecutively. Since logistical constraints made it impossible to sample all stations at the same time or within a narrow "window" of time, this



● MONTHLY SAMPLING STATIONS

Figure 8. Monthly study area

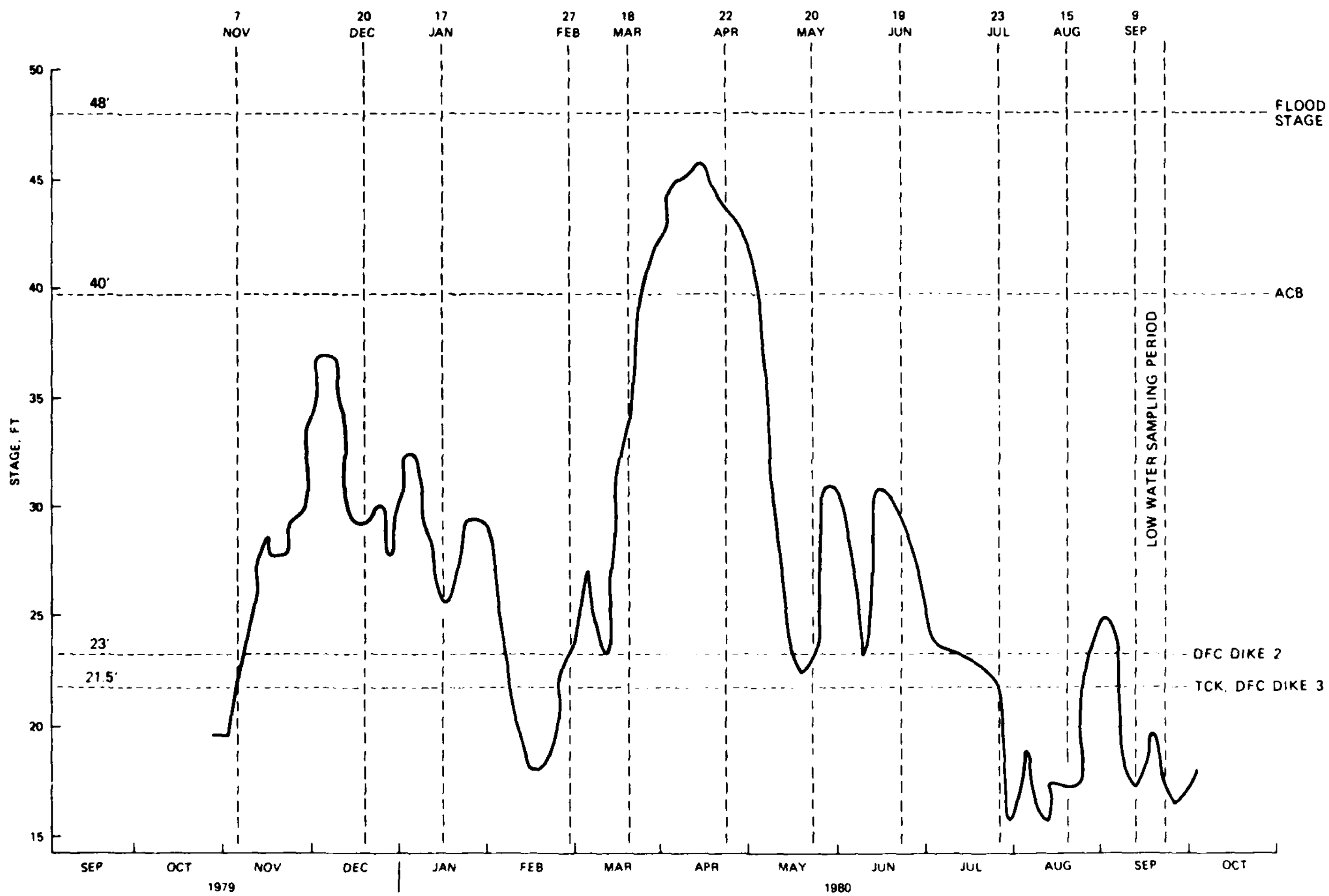


Figure 9. Mississippi river stage at Greenville, Miss.

procedure was used to randomize sampling times at the respective stations. This was used to minimize any possible bias introduced from the diel water quality changes often observed in lentic environments primarily associated with variables such as dissolved oxygen, temperature, and pH.

Low water study

30. From 10-17 September 1980 during a low water period (Figure 9), spatially intensive sampling of three dike fields, Matthews Bend, and American Cutoff was conducted (Figure 1). All habitats had assumed lentic characteristics except for the third pool of Chicot Landing Dike Field, and the American Cutoff. Sampling stations were allocated in lentic habitats in proportion to the pool area at low water stage. The number of stations allocated was as follows: five in Matthews Bend; eleven in Lower Cracraft Dike Field; seven in Leota Dike Field; nine in Chicot Landing Dike Field; five in the main channel; and three in American Cutoff. Sampling point locations within each pool and habitat were randomly selected using a numbered grid overlay. Sampling within a given habitat was begun by midmorning and was performed as quickly as possible. Sampling was always completed by early afternoon. Each day that a particular habitat was sampled, a single main channel station was sampled adjacent to that habitat.

Field Procedures

31. The variables sampled and analyzed are listed in Table 1. Fewer variables were collected and analyzed during the low water study; this was done to minimize the sampling time per station, allowing a greater number of samples to be taken in a short period of time.

32. To determine at what depths samples and measurements should be collected at a given station, a two-tier criterion was used. First, current velocity was measured. If the current was greater than 50 cm/sec,* all additional measurements and sampling were performed only at

* Current velocities above 31 cm/sec were determined (Buglewicz, unpublished data) to be indicative of well-mixed riverine conditions within the portion of the river studied.

the surface (0.5 m). A Secchi disk transparency measurement was then taken. Measurements of temperature, dissolved oxygen, pH, specific conductance, and oxidation-reduction potential (ORP) measurements were then made with an in situ, multivariable water quality probe (Table 1) at the surface only for current velocities above 50 cm/sec, and at a 1-m depth interval from the surface to the bottom for current velocities equal to or less than 50 cm/sec. If stratification* was detected, surface and bottom (0.5 to 1.0 m above bottom) samples were taken for water quality variables requiring laboratory analysis (Table 1).

33. Water quality variables requiring laboratory analysis were collected at the designated sample depth with an 8-ℓ polyvinyl chloride Van Dorn bottle. Portions of the sample were placed in separate containers marked only with a laboratory identification number. The appropriate preservatives (Table 1) were added to the samples. Samples were then stored on ice in the dark until delivery to the laboratory at the U. S. Army Engineer Waterways Experiment Station (within 24 hr) where analysis was conducted.

34. A quality assurance procedure was performed to estimate sampling and analytical variability for the respective variables. At one or more selected stations during each monthly sampling, triplicate samples were taken for all chemical water quality variables requiring laboratory analysis. Each of these triplicates was analyzed independently. Additionally, randomly selected samples were analyzed in duplicate. Results of quality assurance tests are described separately in Appendix A.

Laboratory Procedures

35. Commonly used handling, preservation, and analytic procedures for water quality variables tested in this study are listed in Table 1. In all analyses requiring filtration (except dissolved orthophosphate), Whatman GF/C glass fiber filters were used. The effective pore size of these filters, as stated by the manufacturer, is 1 to 2 μm.

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* Stratification is here defined as a change in temperature with depth of $\geq 1.0°$ C/m, or a change in dissolved oxygen with depth of ≥ 2.0 mg/ℓ/m.

36. The high suspended solids concentration of riverine stations made it difficult to collect and enumerate zooplankton using conventional procedures; therefore, a modified procedure was developed. Zooplankton abundance and total volume by taxa were measured by examination of concentrated subsamples in a Sedgwick-Rafter (S-R) cell at ×100. Identification was carried to genus when possible using the following taxonomic keys: Pennak (1953), Edmondson (1959), and Stemberger (1979). Distinguishable taxa which could not be identified to genus were identified to the lowest possible taxon and then categorized by size class.

37. Zooplankton samples were collected by pumping a known volume of water (between 40 and 100 ℓ) through a 53-μm Nitex plankton net, using two electric bellows pumps. Material retained on the netting was washed into a bottle and preserved with 5 percent buffered formalin. In the laboratory, Eosin y stain was added to the sample; staining helped to distinguish between debris and zooplankton. The sample was then placed in a glass graduated cylinder and allowed to settle. Depending on the expected zooplankton abundance of the sample, it was further concentrated by aspiration suction with a 53-μm mesh net over the suction tube. A 1-mℓ portion was withdrawn with a wide mouth auto pipette while agitating the sample. This portion was placed in an S-R cell and allowed to settle for 10 min prior to examination. Organisms in the entire S-R cell were enumerated and identified. Loricate zooplankton with no protoplasm (dead when preserved) were not counted. Measurements for estimation of biovolume were made on 20 randomly selected individuals for each taxon encountered (American Public Health Association (APHA) 1980). Biovolume from each individual set of measurements was determined and the average biovolume by taxon was computed. Rotifer eggs and cladoceran ephippia, not usually counted in zooplankton studies, were counted in this study as it was decided to measure total zooplankton biovolume (biomass).

Data Reduction and Analysis

38. Because dike fields alter the current regime, the presence or absence of current is stressed in the analysis of data. While bottom water samples were widely collected in lentic habitats, the primary

emphasis in comparison of habitats was on surface waters. Bottom water conditions are analyzed only for variables of particular significance in defining suitability of bottom waters for aquatic life.

39. Surface water quality variables were compared graphically by study period means or by frequency of detection, depending upon the analytical precision, overall variability, and frequency of detection of the respective individual variables. Surface waters in habitats sampled during the low water study period were compared by individual variables using one-way analysis of variance (ANOVA) and Duncan's multiple range test. For variables below a known detection limit (nitrite-nitrate nitrogen, ammonia nitrogen, total phosphorus, and dissolved orthophosphate), the detection limit (Table 1) was used in the computation of means and other statistics (Finney 1978).

40. In addition to the analyses described above, the portion of POM in total suspended solids was graphically compared. The POM was further described by partitioning into algal, zooplankton, and detrital components. Algal POM was estimated by assuming that 1.5 percent of algal organic matter consists of chlorophyll a (APHA 1980). Estimation of zooplankton POM was based upon zooplankton biovolumes. For each sample, unit biovolume for each taxon was multiplied by the numerical density for that taxon; total biovolume for all taxa encountered in the sample was summed, giving a total zooplankton biovolume concentration. A specific gravity of 1.025, a dry weight conversion of 20 percent, and an ash content of 10 percent of dry weight were assumed. These values were generally within the range of values listed in Cummins and Wuycheck (1971) and Jorgensen (1979) for many of the organisms encountered in the zooplankton samples. Detrital POM was estimated by subtracting the computed algal and zooplankton POM components from total POM. There were many potential sources of error, both in the primary measurements taken and in the assumptions used to convert these measurements to ash-free dry weight; the resultant POM components are presented only to describe general trends.

41. Bottom water samples were only collected in lentic habitats that exhibited distinct stratification (either thermal or chemical) as

previously defined. When no bottom samples were collected, bottom conditions were assumed to be similar to the respective surface waters. The frequency of bottom water sampling at a given station in the monthly study is indicative of the portion of time that stratification occurs. During the low water study, the percentage of the total number of areally apportioned, randomly placed sampling stations in a given habitat at which bottom water samples were collected is used as an estimator of the areal percentage of that habitat which was stratified. This type of approximation is used to estimate the areal percentage of bottom waters devoid of oxygen within each habitat. Additionally, the volumetric proportion of lentic habitats devoid of oxygen or with low dissolved oxygen concentrations are approximated by determining the portion of each water quality profile in this condition then computing the depth-weighted mean by habitat.

42. In order to identify variables which might be causally related in surface waters, correlation analyses were performed on several groupings of data:

a. All surface water samples from monthly and low water studies.

b. All surface water samples in which the measured current speed was zero.

c. All main channel stations.

These groupings were selected to compare relationships among surface water variables under all flow conditions with those under strictly lentic and strictly lotic conditions. For each individual correlation, a correlation coefficient R is computed along with a corresponding alpha level which indicates the probability of error in rejecting the hypothesis that the true correlation coefficient for the population equals zero. Correlations with an alpha level of 0.05 or less are referred to as significant and those with an alpha level of 0.01 or less are referred to as highly significant. It should be kept in mind that correlation is only a measure of co-occurrence; highly correlated variables may or may not be causally related; however, a high correlation between variables is usually a good indication that there is some connection between them.

PART IV: RESULTS

43. Results are presented below by individual variable for all stations sampled as part of the monthly study and for all habitats sampled as part of the low water study. Variables are grouped into physical, chemical, and biological categories.

Physical Characteristics

River stage and current speed

44. During the study period, river stage* varied between a low of 15.7 ft (7,360 m^3/sec, estimated flow) on 11 August 1980 to a high of 45.4 ft (34,000 m^3/sec, estimated flow) on 10-13 April 1980. Figure 9 illustrates river stage by date during the study period; the vertical lines represent the sampling dates. The lower three horizontal reference lines represent the approximate stage at which flow in the habitats sampled completely ceases.

45. Monthly study. Based on the presence or absence of detectable flow, the stations sampled during the monthly study are categorized as being lentic or lotic at the time of sampling. The length of time these stations have been in a lentic state when sampled is estimated based on river stage record (Figure 9) and is summarized in Table 2. Matthews Bend was continuously in the lentic state except during the April sampling when a slight current was detected. DFC pool 3 and Kentucky Bend Chute were in a riverine condition except during the November, May, August, and September samplings. DFC pool 1 was in a lentic state half of the times sampled.

46. Monthly current speed measurements are presented in Table 2 and summarized in Table 3. Main channel stations ranged from a low of 93 cm/sec to a high of 242 cm/sec, with an overall mean of 150 cm/sec. Dike field stations ranged from no current to current within the range

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* Recorded at Greenville gauge; 0 on gauge = 11.3 ft above LWRP and 74.9 ft above mean sea level (msl).

of the main channel stations. Mean current speeds when current was detected was 48 cm/sec at DFC pool 1 and 71 cm/sec at DFC pool 3. Mean current speed at TCK-A when current was detected was 93 cm/sec.

47. Low water study. During the low water study period, river stage varied between 16.9 and 19.8 ft. No flow was observed in Matthews Bend or any of the dike field stations except the third pool of Chicot Landing Dike Field which resembles a secondary channel habitat. Riverine conditions prevailed in American Cutoff and, of course, in the main channel. No current measurements were taken during the low water sampling period.

Temperature

48. Monthly study. Surface water temperature data for stations sampled during the monthly study are illustrated in Figure 10. Main channel stations tended to have the coolest temperatures, ranging from a low of 5.0° C in December to a high of 32.0° C in August. Matthews Bend

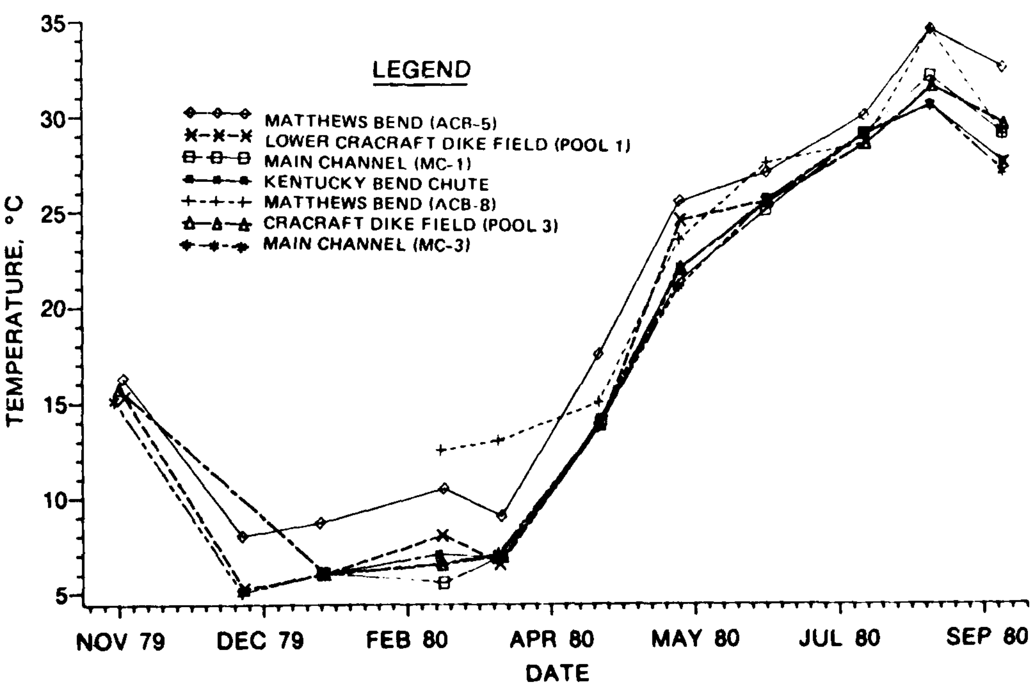

Figure 10. Monthly temperatures

stations tended to be warmest, ranging from a low of 8.0° C in December to 34.5° C in August. Over the study period the monthly mean Matthews Bend surface water temperatures averaged 2.7° C warmer than the corresponding monthly mean for main channel station. Even when flooding of Matthews Bend occurred in April, the surface water temperature averaged 2.3° C warmer than the mean main channel surface water temperature. Surface water temperatures at other stations tended to vary between the lower temperatures of the main channel stations and the higher temperatures of the Matthews Bend stations. DFC pool 1 and pool 3 averaged 0.6° C and 0.4° C, respectively, warmer than the mean for main channel stations. TCK-A was not detectably different from the main channel stations.

49. Monthly bottom water temperatures were only taken at stations with a surface current velocity of less than 50 cm/sec. Only in Matthews Bend were bottom measurements made every month. Bottom temperatures were always detectably less than corresponding surface temperatures. At station ACB-5 surface-to-bottom differences ranged from a low of 1.2° C during the December sampling to a high of 16.0° C during the August sampling. During the April flooding of Matthews Bend, a surface-to-bottom temperature difference of 3.5° C was observed at ACB-5. At shallower station ACB-8, surface-to-bottom differences were generally less; a maximum difference of 5.5° C was observed during the June sampling. At the stations in Lower Cracraft Dike Field and Kentucky Bend Chute, surface-to-bottom temperature differences were only detected in the complete absence of detectable current. Maximum surface-to-bottom temperature differences were 5.0° C, 9.5° C, and 1.0° C for stations DFC pool 1, DFC pool 3, and TCK-A, respectively, and occurred during the warmer sampling months.

50. Low water study. During the low water study period, some significant surface water temperature differences were found between habitats (Table 4). Greatest mean surface temperatures were found in Lower Cracraft Dike Field and Matthews Bend; lowest mean surface temperatures were found in Chicot Landing Dike Field.

51. Bottom water temperature measurements taken in all lentic

habitats during the low water study period showed that the greatest mean surface-to-bottom temperature difference occurred in the deepest habitat, Lower Cracraft Dike Field. Greatest surface-to-bottom temperatures within a habitat were observed at the deepest stations in a given habitat. Unseasonably cold temperatures, 17.3° to 18.7° C, were observed in the bottom of plunge pools behind the first and second dikes in Lower Cracraft Dike Field and behind the second dike in Chicot Landing Dike Field.

Suspended solids

52. Monthly study. Suspended solids data for the monthly study are summarized in Table 3. Station means were greatest for main channel stations and least for Matthews Bend stations, which also exhibited the least variability. Means for stations in Lower Cracraft Dike Field and Kentucky Bend Chute were between the extremes of the main channel and the Matthews Bend stations, and variability for these stations was greater than either main channel or Matthews Bend stations. During lotic periods, mean suspended solids at Lower Cracraft Dike Field and Kentucky Bend Chute stations were similar to the main channel; during lentic periods, means were similar to ACB stations.

53. Low water study. Surface water suspended solids data collected during the low water study period are summarized by habitat in Table 4. Significant differences were detected between lentic and lotic habitats, and among lotic habitats. American Cutoff and the third pool in Chicot Landing Dike Field showed the greatest mean concentrations and were greater than the main channel. The shallower lentic habitats (Matthews Bend, Leota Dike Field, and the first two pools of Chicot Landing Dike Field) had higher mean concentrations than the deeper lentic stations in Lower Cracraft Dike Field.

Transparency

54. Monthly study. Secchi disk transparency data for the monthly study are summarized in Table 3. Main channel stations had the lowest average transparency and the least month-to-month variability of all stations. Matthews Bend stations had the greatest average transparency. Averages for Lower Cracraft Dike Field and Kentucky Bend Chute stations

were between the extremes of main channel and Matthews Bend stations.

55. Low water study. Secchi disk transparency data collected during the low water sampling period are summarized in Table 4. The mean transparency is greatest in Lower Cracraft Dike Field, and least in American Cutoff and the third pool of Chicot Landing Dike Field. In lentic habitats, greater transparency values were observed at the deeper stations within habitats and in the overall deepest lentic habitat (Lower Cracraft Dike Field) among habitats. Among lotic habitats, mean transparency was lower in American Cutoff and the third pool of Chicot Landing Dike Field than in the main channel.

Turbidity

56. Monthly study. Surface water turbidity data during the monthly study are summarized in Table 3. Greatest overall mean turbidity values were found at main channel stations; lowest overall mean values were found at Matthews Bend stations. Overall means at TCK-A and Lower Cracraft Dike Field stations were slightly less than those at main channel stations. During lentic samplings, turbidity values at these stations resembled those of Matthews Bend and during lotic samplings they were similar to those in the main channel.

57. Low water study. Mean surface water turbidity values observed during the low water study were found to be significantly different between habitats (Table 4). Greatest mean turbidities were found in American Cutoff and the third pool of Chicot Landing Dike Field; the lowest mean turbidity was found in Lower Cracraft Dike Field. Those in all other habitats including the main channel were at intermediate levels and not significantly different from each other.

Specific conductance

58. Monthly study. Surface water specific conductance during the monthly study is summarized in Table 3. Overall means for all stations except those in Matthews Bend were similar (ranging from 417 to 433 μmhos/cm). Matthews Bend stations were higher than the others, and the mean for station ACB-8 was greater than the mean for station ACB-5.

59. Over the monthly study period, station-to-station differences were small among stations in habitats other than Matthews Bend

(Figure 11). Specific conductance at Matthews Bend stations was consistently higher than other stations except during the April flooding. Following the flooding, specific conductance quickly rose at Matthews Bend stations.

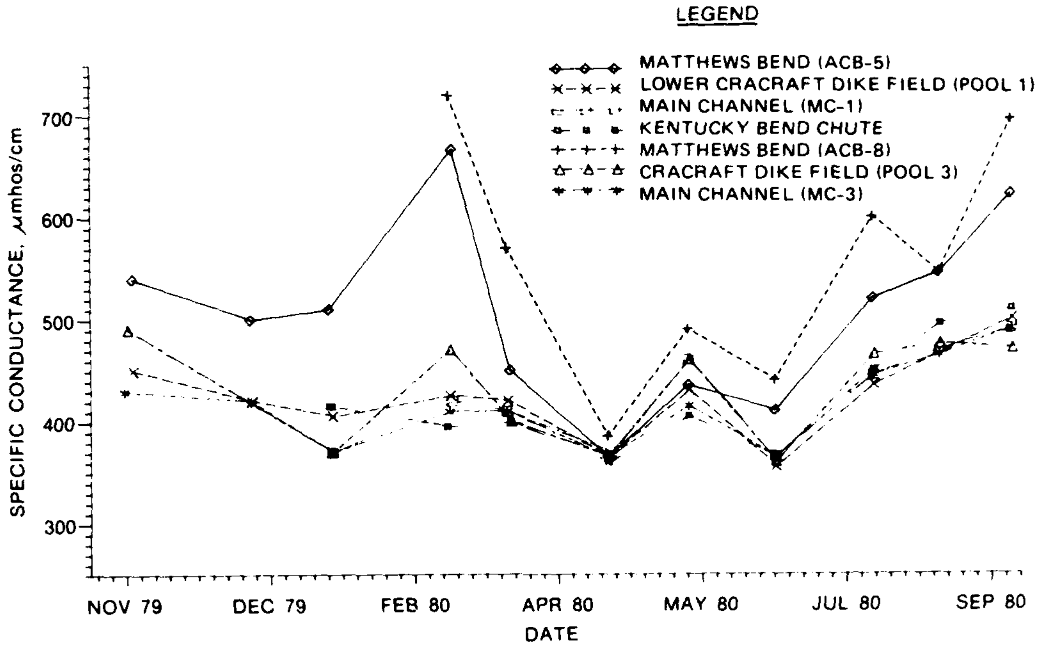

Figure 11. Monthly specific conductance

60. Low water study. During the low water study period, mean surface water specific conductance values were found to be significantly different between habitats (Table 4). The greatest mean specific conductance was found in the lentic portion of Chicot Landing Dike Field, followed by Matthews Bend. The lowest mean surface water specific conductance was found in Lower Cracraft Dike Field.

61. The greatest specific conductance values measured (over 900 μmhos/cm) were found in the bottom of the deep plunge pool behind the first and second dikes in Lower Cracraft Dike Field and behind the second dike in Chicot Landing Dike Field during the low water study.

Chemical Characteristics

Dissolved solids

62. Monthly study. Surface water dissolved solids concentrations during the monthly study are summarized in Table 5. Station means varied from a low of 283.3 mg/ℓ at station DFC pool 1, to a high of 368.5 mg/ℓ at station ACB-8. Concentrations varied most at stations at which lotic conditions prevailed. Continuously lotic stations and intermittently lentic stations under lotic conditions tended to have relatively low dissolved solids for most samplings. During the May sampling, extremely high concentrations were observed at all lotic stations; stations isolated from the river at this time (Matthews Bend and DFC pool 1) had relatively lower concentrations. Excluding the May sampling observation, stations in Matthews Bend tended to exhibit higher dissolved solids concentrations.

63. Low water study. Surface water dissolved solids concentrations during the low water study period are summarized in Table 4. Significant differences existed between surface water mean concentrations for the different habitats. The highest mean concentration was observed in the lentic portion of Chicot Landing Dike Field (447.5 mg/ℓ), followed by Matthews Bend (371.0 mg/ℓ). All other habitats had lower mean concentrations in the range of 263 to 293 mg/ℓ. No significant differences were detected between lotic habitats.

Alkalinity

64. Monthly study. Surface water total alkalinity during the monthly study is summarized in Table 5. Mean total alkalinity was greatest at Matthews Bend stations. With the exception of DFC pool 1 in February, all stations in habitats other than Matthews Bend showed moderate levels of alkalinity and close agreement between stations within a sampling month (Figure 12). Total alkalinity at Matthews Bend stations was consistently much higher than other stations except for ACB-5 in March, when low alkalinity riverine water was rising into the backwater, and for both stations in April when the habitat was flooded.

65. During the monthly study, phenolphthalein alkalinity was

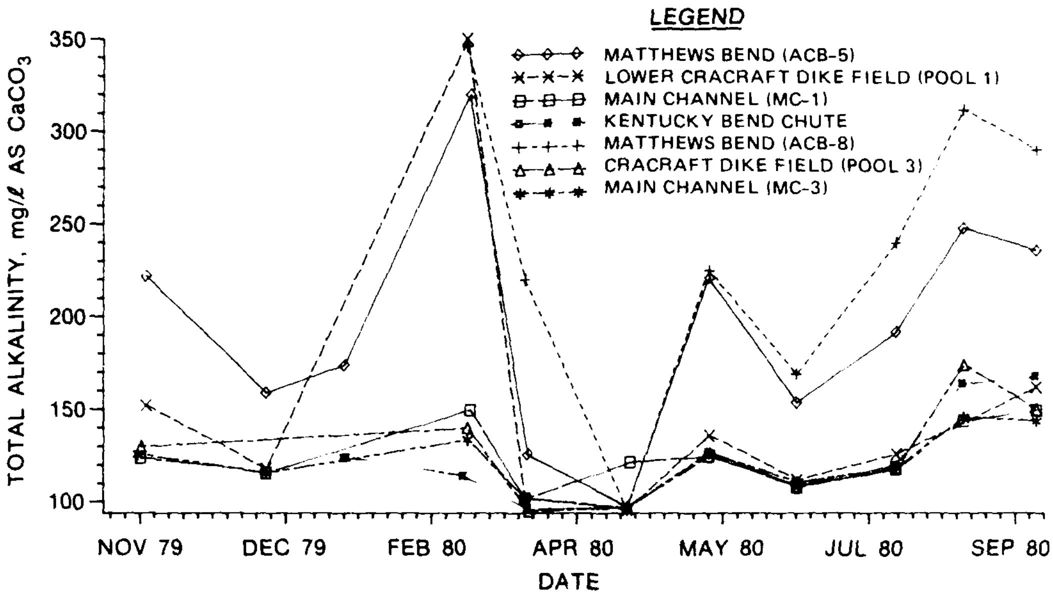

Figure 12. Monthly total alkalinity

never detected at stations in the main channel or Kentucky Bend Chute. Phenolphthalein alkalinity was detected at ACB-5 in June, July, and August, and at ACB-8 in February and August. In Lower Cracraft Dike Field, phenolphthalein alkalinity was detected in pool 1 in February and May, and in pool 3 only in August.

66. Low water study. Surface water total alkalinity during the low water period is summarized in Table 4. Significant differences were detected between habitats. Mean total alkalinity in the upper two pools of Chicot Landing Dike Field was greater than in all other habitats; next largest, and significantly different from all remaining habitats, was Matthews Bend. All other habitats had lower mean total alkalinity, and no statistically significant differences were detected between them.

67. During the low water study, surface water phenolphthalein alkalinity was never detected at main channel, American Cutoff, or Chicot Landing Dike Field stations. In Matthews Bend, Leota Dike Field, and Lower Cracraft Dike Field phenolphthalein alkalinity was detected in 60, 70, and 80 percent, respectively, of the samples collected.

pH

68. Monthly study. Surface water pH values during the monthly study are summarized in Table 5. Means for all individual stations were similar. Main channel stations and TCK-A showed the leas* variability; Matthews Bend stations and DFC pool 1 exhibited the greatest fluctuation over the study period. The greatest pH values (8.9) were observed at DFC pool 1 in February and May.

69. Low water study. Surface water pH values during the low water study are summarized in Table 4. Significant differences were detected between habitats. Greatest mean surface water pH values were found in Lower Cracraft Dike Field, Matthews Bend, and Leota Dike Field; lowest values were found in lotic habitats and the upper two pools of Chicot Landing Dike Field.

70. No pH values outside the 6.5 to 9.0 range, described as suitable for aquatic life (USEPA 1976), were observed at any depth during either the monthly or low water studies.

Free carbon dioxide

71. Monthly study. Surface water free CO_2 concentrations during monthly study are summarized in Table 5. Mean values were similar for all stations except ACB-5 where free CO_2 was detectable less than half the sampling times. Free CO_2 was always detected at TCK-A and main channel stations. Within the Lower Cracraft Dike Field, free CO_2 was undetectable once in pool 1 and twice in pool 3.

72. Low water study. During the low water study, free CO_2 in the surface water was always detected at stations in the main channel, American Cutoff, and the third pool of Chicot Landing Dike Field (pooled range 2.2 to 8.8). Free CO_2 was not detected at any stations in the Lower Cracraft Dike Field. Free CO_2 in surface waters at Matthews Bend, Leota Dike Field, and the upper two pools of Chicot Landing Dike Field was detected at 60, 29, and 75 percent, respectively, of the stations in these habitats. All detectable free CO_2 concentrations in the upper two pools of Chicot Landing Dike Field were very high for surface waters, all 20 mg/ℓ or greater.

Dissolved oxygen

73. Monthly study. Surface water dissolved oxygen concentration and percent oxygen saturation values are summarized in Table 5. Mean percent oxygen saturation was least for main channel stations and greatest for Matthews Bend stations; means for the Lower Cracraft Dike Field stations and TCK-A were between those for main channel and Matthews Bend stations. The least variability was observed at main channel stations and the greatest at Matthews Bend stations; Lower Cracraft Dike Field stations and TCK-A showed intermediate levels of variability. Mean percent oxygen saturation for TCK-A and Lower Cracraft Dike Field stations was determined for lotic and lentic periods. During lotic conditions these stations were similar to main channel stations; during lentic conditions the average was appreciably higher for DFC pool 1 and slightly higher for DFC pool 3 and TCK-A.

74. Bottom water dissolved oxygen concentrations measured in Matthews Bend during the monthly study were all greater than 5 mg/ℓ during the cooler sampling months (November-April). From May to September, bottom waters at Matthews Bend stations were devoid of oxygen. Under lentic conditions, Lower Cracraft Dike Field stations showed a similar pattern; during the cooler months lentic bottom waters contained ample dissolved oxygen, while during warmer months anoxic conditions were observed at the deeper pool 3 station but not at the shallower pool 1 station.

75. Low water study. Surface water dissolved oxygen concentrations during the low water study are summarized in Table 4. Significant differences were detected between some habitats. Surface water percent oxygen saturations were greatest in Lower Cracraft Dike Field and Matthews Bend, and least in the three lotic habitats and the lentic portion of Chicot Landing Dike Field. Mean surface percent oxygen saturation in Lower Cracraft Dike Field, Matthews Bend, and Leota Dike Field was above 100 percent; mean surface percent oxygen saturation in all other habitats was below 100 percent. No individual surface water dissolved oxygen concentrations less than 5 mg/ℓ were encountered.

76. The areal and volumetric percentages of lentic habitats

sampled during the low water study which had low oxygen concentrations are summarized below:

Lentic Habitat	No. of Profiles	Mean Depth m	Percent of Stations With Bottom O_2 Less Than 1 mg/ℓ	Volumetric Portion of Habitat With O_2 Concentration Below 5 mg/ℓ	Below 1 mg/ℓ
Lower Cracraft Dike Field	11	5.20	55	46	21
Leota Dike Field	7	1.46	14	11	6
Chicot Landing Dike Field	4	2.20	50	78	47
Matthews Bend	7	1.64	43	34	22

The Lower Cracraft Dike Field and the lentic portion of Chicot Landing Dike Field had the greatest areal percentage of low oxygenated bottom waters; Leota Dike Field had the lowest percentage. The lentic portion of Chicot Landing Dike Field had the greatest volumetric portion of low oxygenated waters and Leotic Dike Field had the least.

Oxidation-reduction potential

77. For a number of reasons, the ORP of oxygenated or surface waters is not quantitatively interpretable (Wetzel 1975, Gunnison and Brannon 1981). For the purposes of this study, ORP was used solely to indicate the occurrence and extent of conditions suitable for generation of toxic H_2S (ORP values of less than 100 mV (Cole 1979)).

78. Monthly study. During the monthly study, ORP values below 100 mV were observed in bottom waters of Matthews Bend at station ACB-5 in August and September and at station ACB-8 in July. An ORP value below 100 mV was observed in bottom waters of station DFC pool 3 in August.

79. Low water study. During the low water study, ORP was measured in all stations in all habitats, except Matthews Bend (equipment malfunction). The ORP values less than 100 mV were observed only at three stations, in the bottom waters of plunge pools behind the first and second dikes of Lower Cracraft Dike Field and in the deep bottom waters at the upper end of pool 2 in the lentic portion of Chicot Landing Dike Field.

Nitrite-nitrate nitrogen

80. Monthly study. Table 6 contains a summary of surface water nitrite-nitrate nitrogen concentrations during the monthly study. Nitrite-nitrate nitrogen was always detected at MC-3, which also had the highest mean concentration. Mean concentration in ACB-5 was the least, frequently below the detection limit. Mean concentration in DFC pool 1 was between that of MC-3 and ACB-5.

81. During the monthly study period, nitrite-nitrate nitrogen concentrations at ACB-5 were continually low except during the two high water sampling periods when turbid riverine waters were observed at the station (Figure 13). DFC pool 1 concentrations were approximately the same as MC-3 during lotic periods; MC-3 concentrations were greater than DFC pool concentrations during lentic periods.

82. Low water study. Mean surface water nitrite-nitrate nitrogen concentrations during the low water study period are summarized in Table 4. Habitat mean concentrations were similar and greatest in lotic

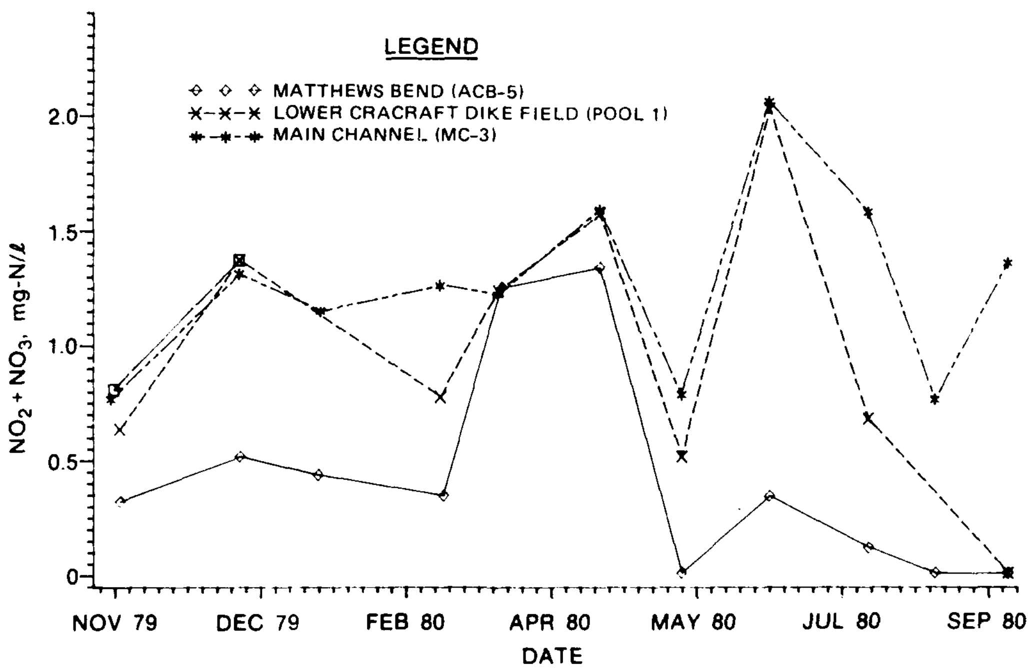

Figure 13. Monthly nitrite-nitrate nitrogen concentrations

habitats, and least in lentic habitats. Within lentic habitats, detectable concentrations of nitrite-nitrate nitrogen were found at 100, 40, 29, and 25 percent of stations in Lower Cracraft Dike Field, Matthews Bend, Leota Dike Field, and the lentic portion of Chicot Landing Dike Field, respectively.

Ammonia nitrogen

83. Monthly study. Surface water ammonia nitrogen concentrations for the three stations sampled during the monthly study are summarized in Table 6. Mean ammonia nitrogen concentrations for all stations were similar, ranging from 0.237 to 0.290 mg/ℓ. Wide fluctuations in ammonia nitrogen concentration were observed at all stations over the study period.

84. Low water study. During the low water study period, surface water ammonia nitrogen concentrations were generally low compared with means for the monthly study period; these values are summarized by habitat in Table 4. Significant differences between some habitats were detected. The highest mean concentration (0.125 mg/ℓ) was found in Matthews Bend and the lowest mean, 0.010 mg/ℓ (i.e., all values at or below detection limit), was found in the lotic portion of Chicot Landing Dike Field.

Total phosphorus

85. Monthly study. Surface water total phosphorus concentrations for the three stations sampled during the monthly study are summarized in Table 6. Total phosphorus concentrations varied widely for all stations, with highest mean concentrations at MC-3 and least at ACB-5.

86. Low water study. Surface water concentrations of total phosphorus for habitats sampled during the low water study period are summarized in Table 4. Significant differences were detected between some habitats. Mean concentrations were greatest and always detected in lotic habitats and in Matthews Bend. Mean total phosphorus was least in Lower Cracraft Dike Field where it was detected in the surface waters only twice out of eleven samples.

Dissolved orthophosphate

87. Monthly study. Surface water dissolved orthophosphate

concentrations during the monthly study are summarized in Table 6. The mean surface water concentration for dissolved orthophosphate was greatest at MC-3 and least at ACB-5. Dissolved orthophosphate was detected in only 4 of 11 samples at ACB-5, in 7 of 9 samples at DFC pool 1, and in every sample at MC-3. Figure 14 illustrates concentrations at the three stations over the monthly study period. Concentrations at ACB-5 were at or near the detection limit for all sampling periods except during the high water months of March and April, and during May. Concentrations at MC-3 were consistently high except during May when concentrations dropped to near detection level. At DFC pool 1, concentrations were similar to those of MC-3 during lotic sampling periods and less than MC-3 during lentic sampling periods.

88. Low water study. Surface water concentrations of dissolved orthophosphate sampled during low water study are summarized in Table 4. Lotic habitats (main channel, American Cutoff, and the lotic portion of Chicot Landing Dike Field) all had relatively high concentrations of dissolved orthophosphate and no significant differences were detected

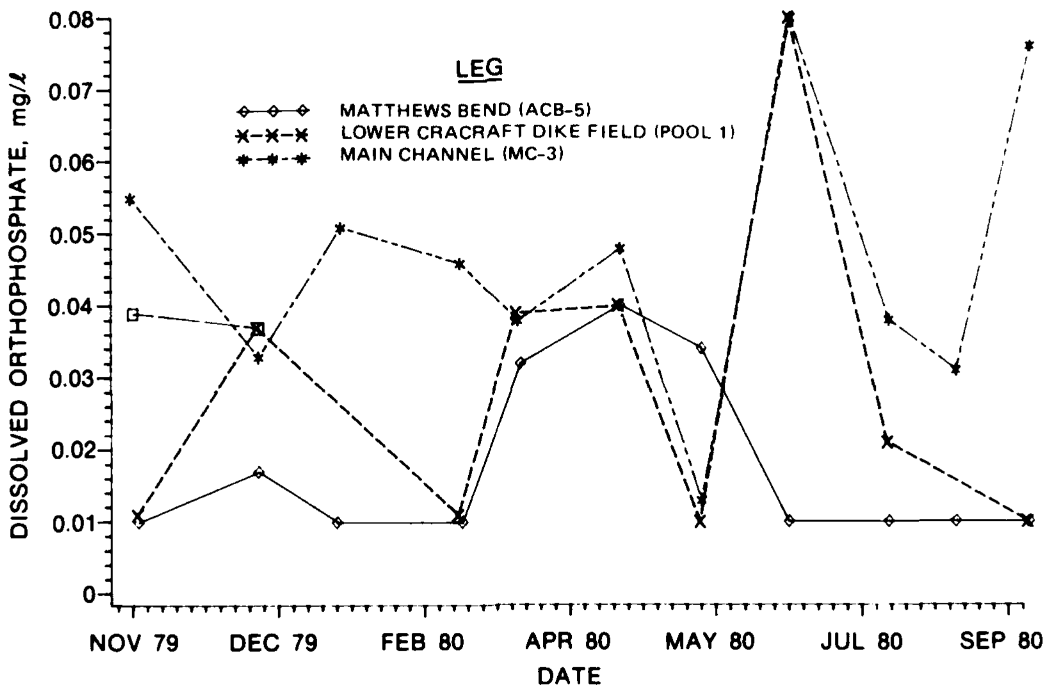

Figure 14. Monthly dissolved orthophosphate concentrations

between them; all lentic habitats had similar concentrations at or near the detection limit.

Biological Characteristics

Photosynthetic pigments

89. Quality assurance evaluation (Appendix A) of the sampling and analytical procedures associated with the photosynthetic pigments indicated that precision was generally poor. The individual pigment showing the greatest sampling and analytical precision was trichromatic chlorophyll *a* (hereafter called chlorophyll *a*). Because of the relatively higher precision associated with this pigment, and because it was common to all taxa of phytoplankton, chlorophyll *a* was the sole pigment used as a quantitative indicator of phytoplankton density.

90. Monthly study. Surface water chlorophyll *a* during the monthly study period is summarized in Table 7. Mean concentrations are lowest and least variable for TCK-A, main channel, and Lower Cracraft Dike Field stations, and greatest and most variable for Matthews Bend stations. Figure 15 illustrates concentrations at the monthly sampling stations over the study period. Main channel stations, TCK-A, and DFC pool 3 continuously had relatively low concentrations, except during a slight rise observed in May and a larger rise observed during the August sampling. Concentrations in Matthews Bend were most frequently greater than those at stations in other habitats, with large peaks in February and August. Concentrations at DFC pool 1 were similar to main channel stations during lotic sampling periods; during lentic sampling periods, concentrations increased above those at main channel stations, but rarely reached the concentrations at Matthews Bend stations.

91. Low water study. Surface water chlorophyll *a* during the low water sampling period is summarized in Table 4. Significant differences were detected between different groupings of habitats. Extremely high concentrations were found in Matthews Bend and the lentic portion of Chicot Landing Dike Field; lowest concentrations were found in lotic habitats.

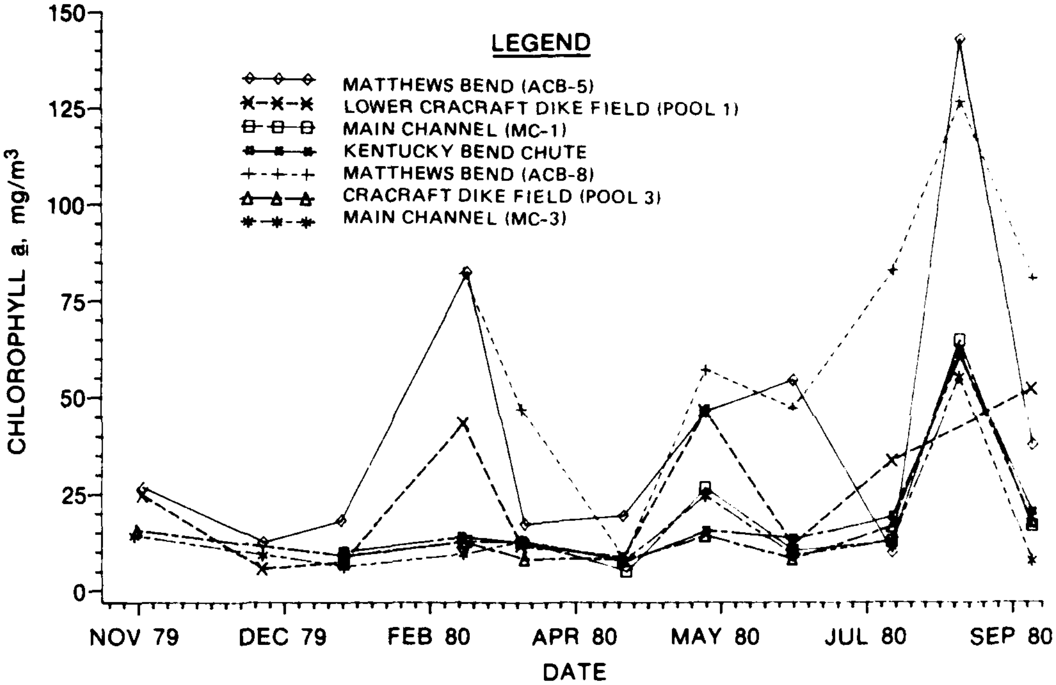

Figure 15. Monthly chlorophyll a concentrations

Zooplankton

92. Monthly study. Zooplankton collected as part of the monthly study (January to September) consisted primarily of loricate rotifers, copepod nauplii, and ciliated protozoans, in that order. Adult copepods, cladocerans, various insect larvae, ostracods, nematodes, and oligochaetes were encountered, although they were numerically rare. The following discussion of zooplankton density is based on number per cubic metre; zooplankton biomass is summarized in the following POM section.

93. Surface water zooplankton numbers at the seven monthly stations sampled are summarized in Table 7. Greatest mean numbers were observed in Matthews Bend stations and least in the main channel stations; the range of means between stations was almost an order of magnitude. Within-station variation over the study period approached two orders of magnitude. Relatively high zooplankton numbers were observed at all stations during the May sampling and at certain individual

stations during July, August, and September (Figure 16).

94. The dominant taxon (representing 1 percent or more of the total number at one or more stations) and major taxonomic groups encountered by stations for all monthly samples pooled over the entire study period are listed in Table 8. At the relatively depauperate main channel stations, *Keratella* (principally *K. cochlearis*), followed by *Vorticella*, copepod nauplii, *Brachionus* (principally *B. calciflorus*), and *Polyarthra* were most numerous. At the zooplankton-rich, continuously lentic Matthews Bend stations, *Brachionus* (*B. angularis*, *B. calciflorus*, and *B. caudata*), *Polyarthra*, *Keratella* (principally *K. cochlearis*), and copepod nauplii, in that order, were most numerous. *Brachionus angularis*, *B. caudata*, *Polyarthra*, *Trichocerca*, *Synchaeta*, *Asplanchna*, *Pompholyx*, *Monostyla*, and *Filinia* were relatively plentiful at one or both of the Matthews Bend stations, but rare at main channel stations. *Vorticella*, plentiful at main channel stations, was relatively scarce at

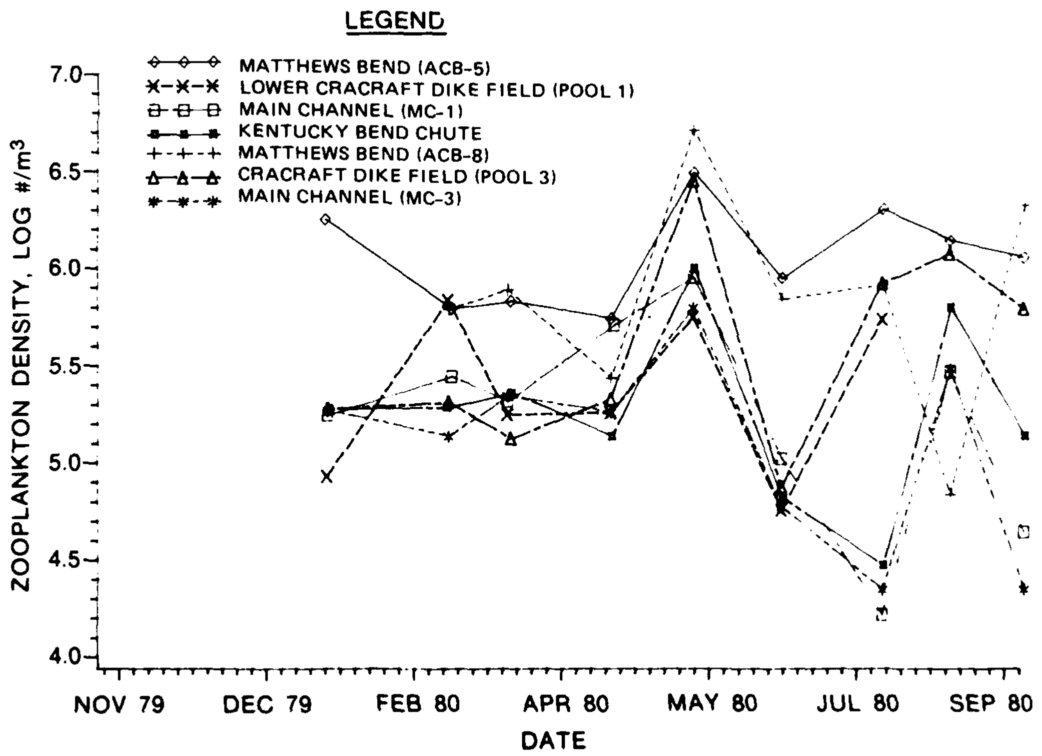

Figure 16. Monthly zooplankton density

Matthews Bend stations. The numbers of *Keratella cochlearis* were similar between Matthews Bend and main channel stations, although it was a much smaller portion of the total zooplankton population at Matthews Bend stations. There appears to be more variation in composition between Matthews Bend stations than between main channel stations. Overall, the percentage of composition of most dominant taxa at the intermittently lentic stations in Kentucky Bend Chute and Lower Cracraft Dike Field was between values at main channel and Matthews Bend stations.

Dissolved organic matter

95. Monthly study. Surface water dissolved organic matter (DOM) concentrations for the stations sampled during the monthly study are summarized in Table 7. Mean DOM concentrations for all stations were similar; however, month-to-month within-station variation was high. The greatest DOM concentration observed during the monthly study period occurred at lotic stations in May.

96. Low water study. Surface water DOM during the low water study is summarized in Table 4. Significant differences were detected between some habitats. The greatest mean DOM concentration occurred in the lentic portion of Chicot Landing Dike Field; the lowest mean DOM concentration occurred in Lower Cracraft Dike Field. Significant differences were detected between lentic habitats. Significant differences were also detected between the lotic portion of Chicot Landing Dike Field and the other lotic habitats; however, the main channel DOM concentration sampled the same day as Chicot Landing Dike Field was approximately the same as that in the lotic portion of Chicot Landing Dike Field.

Particulate organic matter

97. Monthly study. Surface water POM during the monthly study is summarized in Table 7. Mean POM concentrations for all stations were similar. Monthly variations within stations were considerable; minimum POM concentrations at most stations, which were continuously or occasionally lentic, were less than those at continuously lotic stations. At lotic stations, the highest POM concentrations were observed in March and June (Figure 17); high POM concentrations were observed in lentic stations infrequently during the cooler months and more frequently

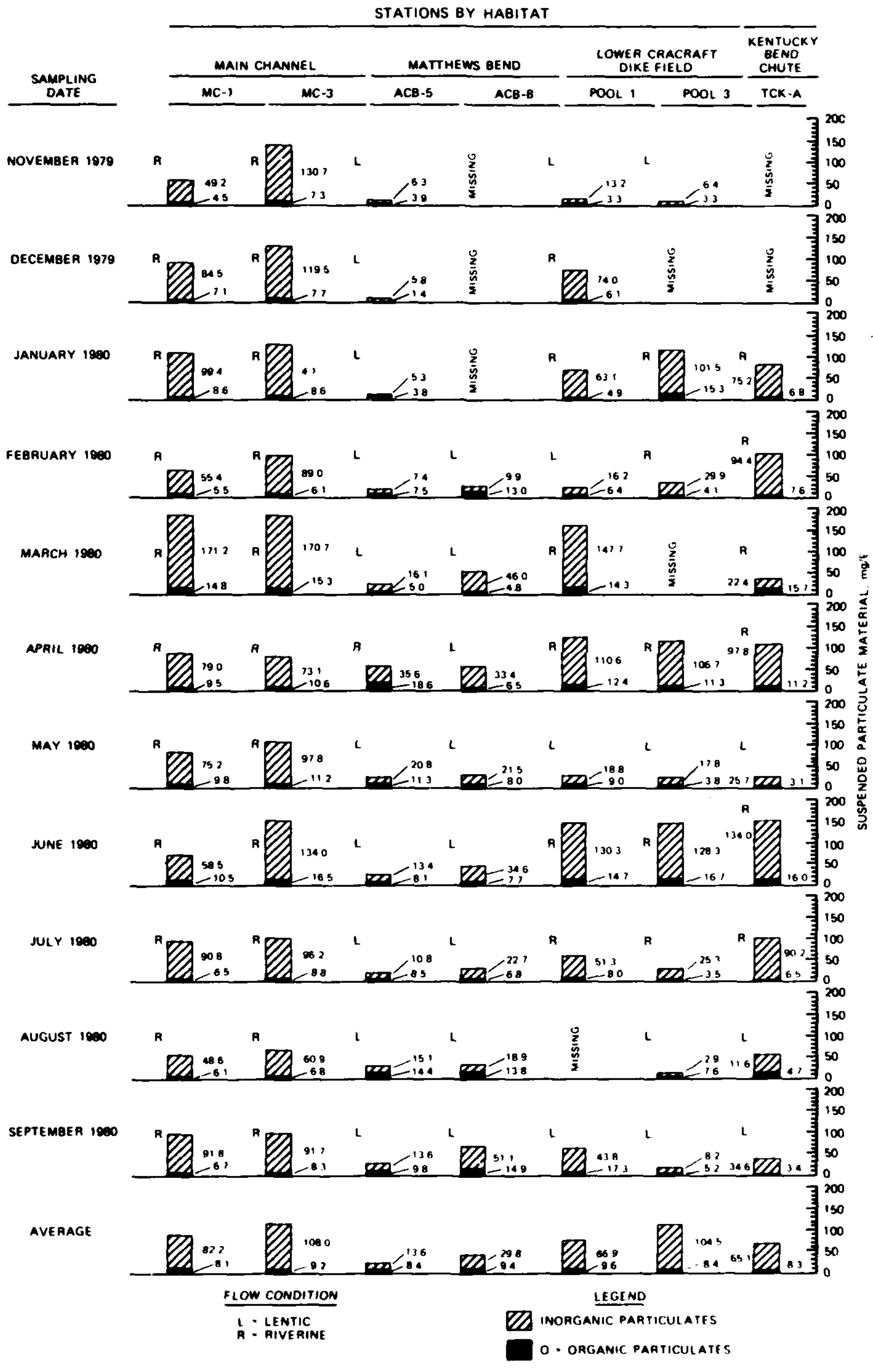

Figure 17. Monthly POM and suspended solids

during the warmer months. The greatest single POM concentration measured during the entire monthly study was observed at ACB-5 in April; presumably this was due to the flooding of the terrestrial habitat immediately adjacent to this habitat.

98. The portion of organic and inorganic particulates in total suspended solids is illustrated for the monthly and low water studies in Figure 17. While organic particulates remained nearly constant across all stations, habitats, and sampling dates, inorganic particulates were greatly reduced under lentic conditions. Therefore, organic particulates generally make up a larger portion of the total suspended particulate material under lentic conditions than under lotic conditions.

99. The POM samples collected monthly were partitioned into algal, zooplankton, and detritus components as described in paragraph 39. Results are illustrated in Figure 18. Samples were deleted in which any one of the three needed measurements were missing. Overall, main channel stations had the greatest detrital component and the least algal and zooplankton components; the reverse appears true at Matthews Bend stations. Detrital POM at main channel stations made up over 80 percent of the total POM for all samples except those in August when algal POM was greater than half the total POM. At Matthews Bend stations algal POM contributed over 20 percent of the total for all samples except during the April flooding and at ACB-5 in July. At TCK-A and Lower Cracraft Dike Field stations, total POM was greatest during lotic periods with compositions resembling the main channel; under lentic conditions, total POM was generally lower and consisted of greater parts of algal and zooplankton POM. Zooplankton were never a major constituent of POM in any sample. At main channel stations, zooplankton POM averaged 0.3 percent and was never greater than 1.8 percent of total POM (0.18 mg/ℓ) in any individual sample. Zooplankton POM at other stations was generally larger with a maximum overall study period mean of 0.31 mg/ℓ (3.4 percent) at station ACB-5, and maximum single value of 1.15 mg/ℓ (14 percent) observed at station ACB-8 in May.

100. <u>Low water study.</u> Surface water POM during the low water study is summarized in Table 4. Significant differences were detected

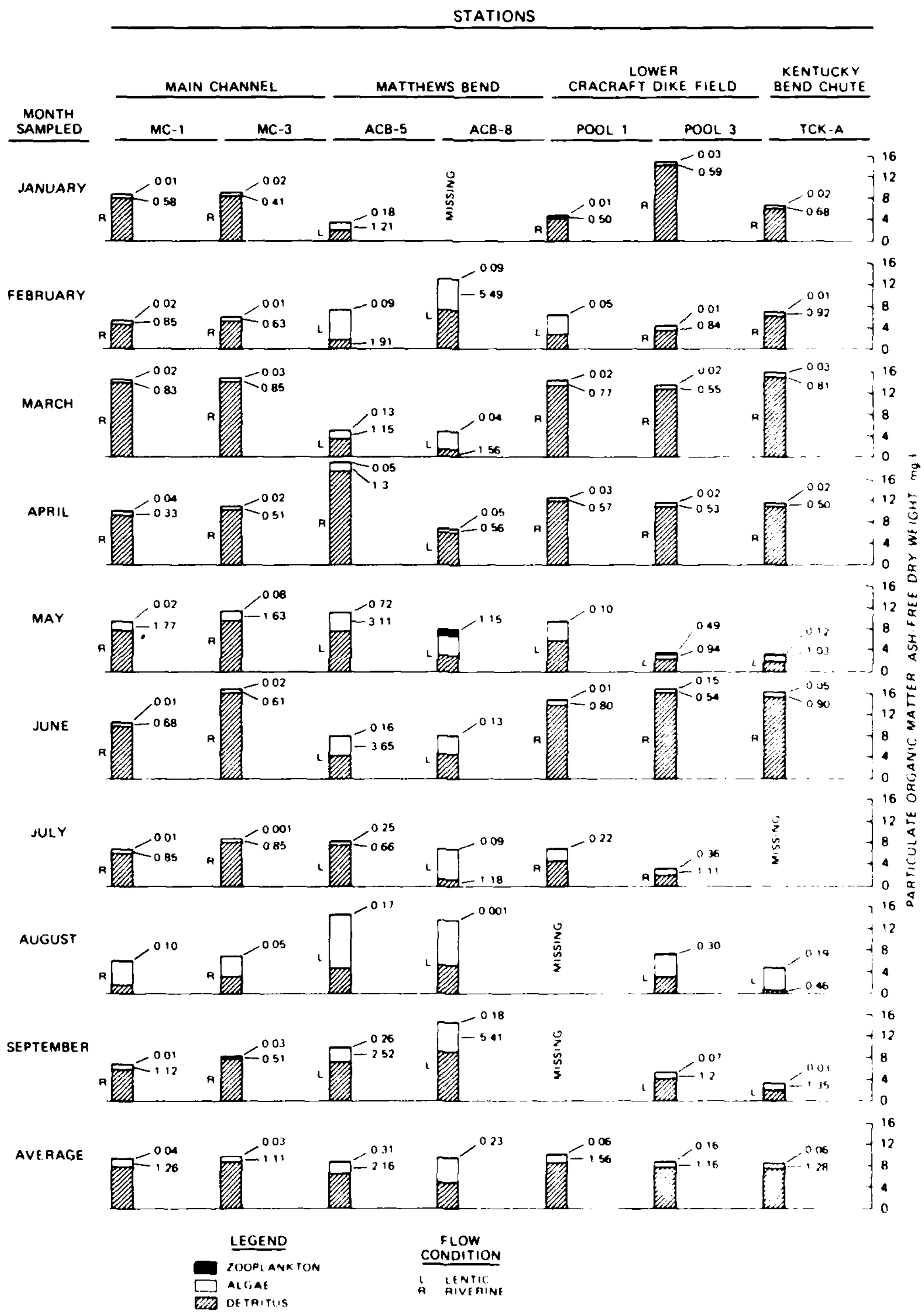

Figure 18. Monthly POM partitioned into detritus, algal, and zooplankton components

between habitats. The mean POM in Matthews Bend was significantly greater than all other habitats, for which no differences were detected. Analysis of organic and inorganic particulates within the total suspended solids (Figure 19) again shows that organic particulates remain nearly constant under all flow conditions whereas inorgainc particulates tended to increase under flowing water conditions.

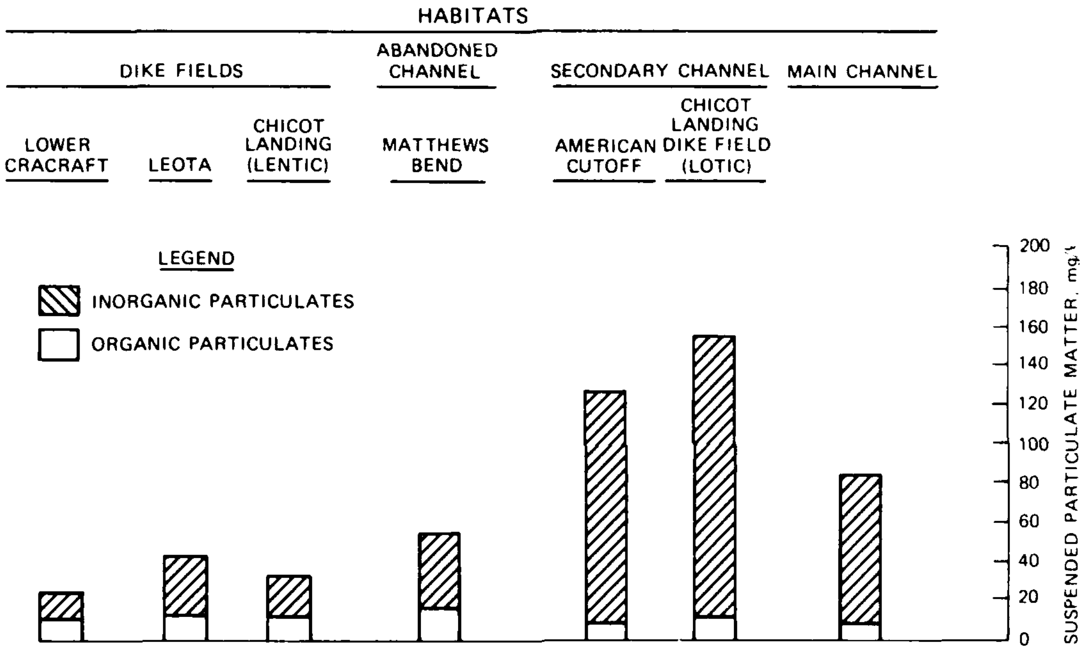

Figure 19. Low water POM and suspended solids

Correlation Analysis

101. Correlation analyses of selected water quality variables in surface water samples for all stations, main channel samples only, and lentic samples only are summarized in Figures 20, 21, and 22, respectively. Only significant correlations are indicated. Under the wide range of current velocities found among all surface samples, many significant correlations were found. Among strictly lotic and strictly lentic samples, relatively fewer significant correlations were found.

	CURRENT* SPEED	TEMPERATURE	SUSPENDED SOLIDS	SECCHI TRANSPARENCY	TURBIDITY	DISSOLVED SOLIDS	SPECIFIC CONDUCTANCE	TOTAL ALKALINITY	pH	FREE CO_2	% O_2 SATURATION	$NO_2 + NO_3$	NH_3	TOTAL PHOSPHORUS	DISSOLVED ORTHOPHOSPHATE	CHLOROPHYLL a	ZOOPLANKTON DENSITY	DOM	POM
POM/SUSPENDED SOLIDS	--	++	--	++	--		++		++		++	--		--	-	++	++		++
POM		++	++	--	+						+					++		+	
DOM				--		++				+									
ZOOPLANKTON DENSITY	--		--	++	--	++	++	++			++	--			--	++			
CHLOROPHYLL a	--	++	--	+	--	++	++	++	++		++	--		--	--				
DISSOLVED ORTHOPHOSPHATE	++		++	--	++	-	--	--			--	++		++					
TOTAL PHOSPHORUS			++	--	++		--	--	--		--	++							
NH_3		--			+		-		--			++							
$NO_2 + NO_3$	++	--	++	--	++	--	--	--	--		--								
% O_2 SATURATION	--	++	--	++	--				++	--									
FREE CO_2				-	++	++	++	++	--										
pH	--	++	--	++	--														
TOTAL ALKALINITY	--	+	--	+	--	++	++												
SPECIFIC CONDUCTANCE	--	++	--	++	--	++													
DISSOLVED SOLIDS	-	++	--		--														
TURBIDITY	++	--	++	--															
SECCHI TRANSPARENCY	--		--																
SUSPENDED SOLIDS	++	--																	
TEMPERATURE	--																		

LEGEND

+ = SIGNIFICANT POSITIVE CORRELATION ($p \leq 0.05$)
++ = HIGHLY SIGNIFICANT POSITIVE CORRELATION ($p \leq 0.01$)
- = SIGNIFICANT NEGATIVE CORRELATION ($p \leq 0.05$)
-- = HIGHLY SIGNIFICANT NEGATIVE CORRELATION ($p \leq 0.01$)

NOTE ONLY CORRELATIONS WITH $p \leq 0.05$ ARE INDIC

* LOW WATER SAMPLING STATIONS NOT INCLUDED

Figure 20. Correlation analysis of water quality variables for all surface samples

	RIVER FLOW	TEMPERATURE	SUSPENDED SOLIDS	SECCHI TRANSPARENCY	TURBIDITY	DISSOLVED SOLIDS	SPECIFIC CONDUCTANCE	TOTAL ALKALINITY	pH	FREE CO_2	% O_2 SATURATION	$NO_2 + NO_3$	NH_3	TOTAL PHOSPHORUS	DISSOLVED ORTHOPHOSPHATE	CHLOROPHYLL *a*	ZOOPLANKTON DENSITY	DOM	POM
POM/SUSPENDED SOLIDS			- -																
POM			+ +	- -	+		-					+		+ +					
DOM						+ +											+ +		
ZOOPLANKTON DENSITY						+ +						-			- -				
CHLOROPHYLL *a*	-	+ +	-	+ +	- -		+		+ +		+	-							
DISSOLVED ORTHOPHOSPHATE																			
TOTAL PHOSPHORUS				-							-	+							
NH_3											+								
$NO_2 + NO_3$				- -	+														
% O_2 SATURATION		-		+					+										
FREE CO_2																			
pH	-			+															
TOTAL ALKALINITY				+															
SPECIFIC CONDUCTANCE	- -	+ +		+ +	- -														
DISSOLVED SOLIDS					-														
TURBIDITY	+ +	- -	+ +	- -															
SECCHI TRANSPARENCY	-		-																
SUSPENDED SOLIDS		-																	
TEMPERATURE	- -																		

LEGEND

+ = SIGNIFICANT POSITIVE CORRELATION ($p \leq 0.05$)
++ = HIGHLY SIGNIFICANT POSITIVE CORRELATION ($p \leq 0.01$)
- = SIGNIFICANT NEGATIVE CORRELATION ($p \leq 0.05$)
-- = HIGHLY SIGNIFICANT NEGATIVE CORRELATION ($p \leq 0.01$)

NOTE ONLY CORRELATIONS WITH $p \leq 0.05$ ARE SHOWN

Figure 21. Correlation analysis of water quality variables for main channel samples only

	TEMPERATURE	SUSPENDED SOLIDS	SECCHI TRANSPARENCY	TURBIDITY	DISSOLVED SOLIDS	SPECIFIC CONDUCTANCE	TOTAL ALKALINITY	pH	FREE CO_2	% O_2 SATURATION	$NO_2 + NO_3$	NH_3	TOTAL PHOSPHORUS	DISSOLVED ORTHOPHOSPHATE	CHLOROPHYLL a	ZOOPLANKTON DENSITY	DOM	POM
POM/SUSPENDED SOLIDS		-						++		++	-				++			++
POM	++	++	--			+	+			+	--				++			
DOM			--		++													
ZOOPLANKTON DENSITY									++									
CHLOROPHYLL a	+		--			++	++		++		--							
DISSOLVED ORTHOPHOSPHATE											+							
TOTAL PHOSPHORUS				++														
NH_3	--										++							
$NO_2 + NO_3$	--	-	+			-												
% O_2 SATURATION	++							++	--									
FREE CO_2			-	++	+	++	++	--										
pH				-		-												
TOTAL ALKALINITY			-			++												
SPECIFIC CONDUCTANCE			-		++													
DISSOLVED SOLIDS			--															
TURBIDITY																		
SECCHI TRANSPARENCY	-	--																
SUSPENDED SOLIDS																		

LEGEND

\+ = SIGNIFICANT POSITIVE CORRELATION ($p \leq 0.05$)
++ = HIGHLY SIGNIFICANT POSITIVE CORRELATION ($p \leq 0.01$)
\- = SIGNIFICANT NEGATIVE CORRELATION ($p \leq 0.05$)
-- = HIGHLY SIGNIFICANT NEGATIVE CORRELATION ($p \leq 0.01$)

NOTE ONLY CORRELATIONS WITH $p \leq 0.05$ ARE INDICATED

Figure 22. Correlation analysis of water quality variables for lentic surface samples only

PART V: DISCUSSION

102. In this discussion of the data, the interaction of flow with the respective variables is described and each habitat type is characterized in terms of these variables. The findings of this study are compared with similar types of studies on other river systems to assess geographic limitations of these findings. Additionally, insights into riverine sampling design, produced by this study, are discussed.

Characterization and Comparison of Habitats

103. Among the diverse conditions represented by the data containing all surface water samples, sharp contrasts are exhibited between lentic and lotic waters. The presence of current tends to be associated with relative extremes in many of the chemical, biological, and other physical water quality variables; for example, the following variables can be characterized as being at the following *relative levels when* current is present (from Figure 20):

Relatively High Levels	Relatively Low Levels
Suspended solids (and turbidity)	Water transparency
Soluble plant nutrients	Temperature
	Dissolved substances*
	Oxygen saturation
	Autochthonous organic matter**
	pH

Relatively high levels of suspended solids and low water transparency, presumably resulting from turbulence created by current, tend to be associated with the following relative levels of the following chemical and biological variables (from Figure 20):

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* Indicated by total alkalinity, specific conductance, and dissolved solids.
** Indicated by chlorophyll a and zooplankton density.

Relatively High Levels	Relatively Low Levels
Soluble plant nutrients	Dissolved substances
POM	Oxygen saturation
	Autochthonous organic matter
	pH

How the respective water quality variables associate with (or respond to) current or other physical conditions controlled by currents determines to a large degree the water quality characteristics of a given habitat.

104. Under flowing water conditions, high turbulence and/or the associated high suspended solids concentration and consequent low light penetration presumably act to retard aquatic primary production, resulting in generally lower and more stable pH and percent oxygen saturation levels (also affected by the high reaeration rate under turbulent conditions), and higher concentrations of readily available algal nutrients. Under lentic conditions, water transparency is greater, and aquatic primary production occurs resulting in higher pH and percent oxygen saturation levels and lower concentrations of readily available algal nutrients.

Main channel

105. The main channel had a consistently high suspended solids concentration with corresponding low water clarity. Greatest suspended solids concentrations were observed in March as river stage rose during spring high water; lowest concentrations were observed in August during a low flow period. Suspended solids concentrations showed no significant correlation with riverflow (Figure 21), although both turbidity and Secchi disk transparency did. Based on an estimated photic zone depth to 3.0 times the Secchi disk transparency depth (Cole 1979), the mean depth of the photic zone in the main channel is only 70 cm.

106. Dissolved substances, as indicated by dissolved solids, total alkalinity, and specific conductance, showed relatively minor variations during most months in the study period. During the May sampling, a twofold rise in dissolved solids was observed; this corresponded with an

equally sharp rise in DOM, but only minor changes in specific conductance and total alkalinity. This would indicate that this pulse of dissolved material was not principally electrolytes. This is further illustrated by the lack of significant correlation between dissolved solids and specific conductance in main channel waters (Figure 21). Specific conductance cannot therefore be accurately used to estimate dissolved solids in the Mississippi River, as is a common practice (Krenkel and Novotny 1980). This would indicate that the specific composition of substances and ions which comprise dissolved solids changes over time, probably representing the sampling of different parcels of water from different tributaries within the watershed.

107. The pH within the main channel also showed only minor variations over the study period. Minimum values were observed during the April high flow and maximum values were observed during the August low flow. The pH values tended to decrease with riverflow and increase with oxygen saturation and chlorophyll a concentration (Figure 21), indicating a positive association with photosynthetic activity.

108. The actual dissolved oxygen concentration of any water sample is a function of physical, chemical, and biological factors. Since dissolved oxygen data have been normalized to percent oxygen saturation, variation attributable solely to seasonally varying temperature (primary physical factor affecting saturation concentration) has been eliminated and any deviation from saturation can be attributed to biological and chemical processes alone. During active photosynthesis there will be some diel variation in dissolved oxygen. Oxygen consumed by nonalgal respiration or chemical oxidation generally exhibits no diel pattern (Krenkel and Novotny 1980). In the monthly study, sampling time at a given station was continually changed over the study period, in effect randomizing the sampling time. Therefore, the variability in percent oxygen saturation over the study period is as important as the overall mean percent oxygen saturation in making inferences about biological and chemical activity in a habitat. Main channel dissolved oxygen levels, expressed as percent saturation, were quite stable, averaging approximately 90 percent. The stable and almost continual deficit of oxygen

would suggest that biological respiration (chemical oxidation is generally of minor importance in unpolluted waters) has a greater influence on the oxygen regime than does photosynthesis. Further, the greater relative importance of respiration is suggested by the negative correlation between temperature and percent oxygen saturation in the main channel (Figure 21). As temperature rises, biological metabolic rates increase and percent oxygen saturation drops, suggesting that biological processes which consume oxygen (respiration) have a greater influence on oxygen levels than processes which produce oxygen (photosynthesis).

109. Readily available algal nutrients (NO_2 + NO_3 and dissolved orthophosphate) were always present in detectable quantities. This would suggest that phytoplankton growth is not nutrient limited within the main channel environment. Nitrite-nitrate nitrogen and total phosphorus concentrations tended to be higher in turbid water although none of these nutrients showed a significant correlation with suspended solids in the main channel (Figure 21). Total phosphorus did show a highly significant positive correlation with POM, suggesting that the bulk of total phosphorus is bound to organic particulates.

110. Main channel chlorophyll a concentrations were consistently low except for a sharp rise in August and a lesser rise in May. Chlorophyll a concentration in the main channel showed negative associations with flow, suspended solids, turbidity, and nitrite-nitrate nitrogen and positive associations with temperature, Secchi disk transparency, specific conductance, pH, and oxygen saturation (Figure 21). The strong positive association with Secchi disk transparency (and strong negative association with turbidity) would suggest that light and/or turbulence are principal factors which limit photosynthesis.

111. The rotifer-dominated zooplankton community within the main channel was greatest in May, during the first low water period in spring, and lowest during July. Zooplankton numbers showed positive associations with dissolved solids and DOM and negative association with nitrite-nitrate nitrogen and dissolved orthophosphate. The overall numeric dominant within the main channel was *Keratella cochlearis*. The second most numerous taxon was the stalked protozoan *Vorticella*. As

Vorticella normally attaches to substrates (Kudo 1966), their abundance in the main channel could indicate that they had been scoured from their substrate by the swift current in that habitat.

112. The POM in the main channel represents a generally small and constant portion (approximately 8 percent) of the total particulate material in suspension (Figure 17). The composition of the POM was almost entirely detritus for all sampling periods except for August when algae were estimated to comprise over 50 percent of the total POM. Zooplankton never consisted of more than a miniscule portion of the total POM in any single sample.

Abandoned channel

113. The lentic abandoned channel habitat, represented by Matthews Bend, consistently had the warmest surface waters, averaging 2.7° C warmer than the main channel. Distinct thermal stratification was observed at both sampling stations during most samplings. Suspended solids concentrations were comparatively low, averaging less than a third of the mean for the main channel. Water clarity (as indicated by turbidity and Secchi disk transparency) was much greater than in the main channel; mean estimated photic zone depth for the study period was 155 cm. Water clarity in lentic surface waters (Figure 22) tended to decrease with suspended solids and chlorophyll a; thus, chlorophyll a contributes significantly to light extinction, unlike chlorophyll a under lotic conditions.

114. Dissolved substances were generally greater in Matthews Bend than in other habitats. Minimum concentrations within the habitat were observed during spring flooding. Unlike in the main channel, specific conductance showed highly significant positive correlation with dissolved solids and total alkalinity under lentic conditions (Figure 22). This would indicate that the specific composition of ions and substances comprising dissolved solids was relatively stable over the study period.

115. Station ACB-8, the Matthews Bend station farthest from confluence with the main channel, consistently showed specific conductance and concentrations of dissolved solids and alkalinity greater than ACB-5, the station near the confluence with the river. The generally

high levels of dissolved substances in this habitat were probably the result of local surface and groundwater input. The upstream end of the habitat probably undergoes little or no exchange of water with the river in comparison to the downstream and river stage fluctuations below 40 ft on the Greenville gauge (Figure 9). Thus, high levels of dissolved substances accumulating in Matthews Bend would be diluted with main channel waters at the downstream end of the habitat.

116. The pH fluctuations in Matthews Bend surface waters were greater than those within the main channel (Table 5). The pH values under lentic conditions tended to decrease with turbidity, specific conductance, and free CO_2 and increased with percent oxygen saturation and the ratio of POM to suspended solids (Figure 22).

117. Surface water in Matthews Bend showed greater oxygen deficits and supersaturation than other habitats. Bottom waters tended to be devoid of oxygen during the warmer sampling months. Percent oxygen saturation showed a strong positive association with temperature (Figure 22), just the opposite of that correlation observed for lotic surface samples. As previously discussed, this would point to the relatively greater importance of photosynthetic production over heterotrophic respiration.

118. All algal nutrient concentrations were generally much lower in Matthews Bend than in the main channels (Table 6). High concentrations were observed in Matthews Bend during the spring flooding when concentrations rose to equal those of the main channel. Nitrite-nitrate nitrogen and dissolved orthophosphate exhibited almost identical patterns (Figures 13 and 14), being at or near the detection level for all sampling except during spring. Of the four nutrient forms analyzed, nitrite-nitrate nitrogen was most frequently correlated with other variables under lentic conditions (Figure 22) and was the only nutrient form showing any significant correlation (negative) with chlorophyll *a*.

119. Matthews Bend surface waters contained the greatest level of algal biomass (as indicated by chlorophyll *a*) among all habitats (Table 7); mean chlorophyll *a* concentration was over three times that of the main channel. Under lentic conditions, chlorophyll *a* showed a

strong positive association with temperature, specific conductance, total alkalinity, free CO_2, POM, and the ratio of POM to suspended solids, and a strong negative association with Secchi disk transparency and nitrite-nitrate nitrogen (Figure 22). (Algae contribute significantly to light extinction and POM under lentic conditions.)

120. Zooplankton numbers in Matthews Bend averaged almost an order of magnitude greater than in the main channel and were almost consistently greater than numbers in other habitats (Table 8). Greatest numbers were observed in May. Over the entire period of zooplankton sampling (January to September), the overall dominant genus was the rotifer *Brachionus*, consisting of three species (Table 8); *Polyarthra* was the second most numerous genus. While *Keratella cochlearis* (dominant in main channel) was present in almost equal numbers as in the main channel, it was relatively less abundant in Matthews Bend. *Vorticella* was also relatively scarce in Matthews Bend. The taxa were far more varied between Matthews Bend stations than between main channel stations.

121. Overall surface water POM concentrations in Matthews Bend were similar to those in the main channel (Figure 17); however, POM in Matthews Bend represented a far greater portion of the total material in suspension (over 30 percent). Autochthonous organic matter (algae and zooplankton) made up a far greater portion of total POM than in the main channel (Figure 18). Algal POM at one or more of the Matthews Bend stations comprised over a third of the total POM in February and every sampling month from April to September.

Secondary channel

122. Water quality conditions found at the Kentucky Bend Chute station were virtually indistinguishable from those of the main channel when flow was detected at the sampling station. During the three samplings when lentic conditions were observed, May, August, and September, deviations of water quality conditions from those of the main channel were relatively minor. During these samplings, surface water temperatures were not detectably different from main channel temperatures; dissolved solids, specific conductance, total alkalinity, dissolved oxygen, pH, chlorophyll *a*, and zooplankton densities also showed no appreciable

difference from the main channel. Suspended solids and turbidity were greatly reduced during these periods.

123. Other secondary channel habitats sampled during the low water study, American Cutoff and the third pool of Chicot Landing Dike Field, showed no significant chemical differences from the main channel for most variables (Table 4). Significant differences were found between the main channel and the third pool of Chicot Landing Dike Field for pH and DOM. These differences are believed to be an artifact of the sampling design and are discussed in the section on sampling methodology.

124. Significant differences were found between the main channel and the secondary channels for suspended solids, Secchi disk transparency, and turbidity (Table 4). Both secondary channel habitats contained higher suspended solids and turbidity, and lower Secchi disk transparency than the main channel.

Dike field

125. Water quality conditions at the monthly sampling stations in Lower Cracraft Dike Field were very similar to main channel conditions when lotic conditions prevailed. During samplings when lentic conditions were observed, water quality conditions deviated from the corresponding main channel conditions.

126. Surface temperatures during lentic samplings averaged 1.4° and 0.8° C warmer than the main channel for stations DFC pool 1 and DFC pool 3, respectively, and 1.7° C cooler than the corresponding surface means for Matthews Bend. Surface-to-bottom temperature differences up to 5° C were observed at station DFC pool 1, and up to 9.5° C at the deeper DFC pool 3 station; these differences were generally less than corresponding differences at Matthews Bend stations.

127. Suspended solids concentrations and water clarity during lentic samplings tended to resemble those of Matthews Bend.

128. Dissolved substances at monthly dike field stations were generally similar to those of the main channel during all sampling periods. With a single exception (total alkalinity at station DFC pool 1 in February), concentrations at the dike field stations never resembled Matthews Bend stations during the nonflooding periods. Dike field

stations tended to have slightly higher concentrations than main channel stations during lentic samplings with the deviation being greatest during the longest periods of isolation.

129. Surface water pH values exhibited greater fluctuation at station DFC pool 1 than any other station. Peak values (pH = 8.9) occurred in February and May during lentic periods. Active photosynthesis was occurring at these times based on the observed supersaturation of oxygen (4 to 7 mg/ℓ greater than corresponding main channel concentrations) and the relatively high chlorophyll a concentrations. Based on these two indicators of photosynthetic activity, relatively greater photosynthetic activity occurred at both Matthews Bend stations during these same sampling periods; however, surface pH values in Matthews Bend were substantially less, averaging 8.4 and 7.8 for February and May, respectively. In the relatively less buffered waters of Lower Cracraft Dike Field, a given level of photosynthetic activity will result in a far greater pH elevation than in the well-buffered waters of Matthews Bend.

130. Concentrations of readily available algal nutrients (nitrite-nitrate nitrogen and dissolved orthophosphate) at station DFC pool 1 during lentic sampling periods were always less than corresponding concentrations in the main channel, and frequently greater than corresponding concentrations in Matthews Bend. Dissolved orthophosphate concentrations were more frequently below the detection level than were nitrite-nitrate nitrogen concentrations.

131. Chlorophyll a and oxygen saturation, indicators of algal presence and photosynthetic activity, were high in this habitat, at one or both stations during every lentic sampling period except November (Figure 15). The respective concentrations were always below the corresponding concentration in Matthews Bend. During each sampling period when both stations in the dike field were lentic (and were sampled), DFC pool 1 always showed greater concentrations of both variables. This may in part be attributable to the fact that at any time both stations are lentic, DFC pool 1 will have been isolated longer, therefore allowing greater time for algal development.

132. Overall mean zooplankton numbers in Lower Cracraft Dike Field were between those of the main channel and Matthews Bend (Table 7, Figure 16). Peak number in the habitat was observed in May at DFC pool 3. During most samplings, numbers were greater at DFC pool 3 than DFC pool 1; the overall average for DFC pool 3 was over twice that of DFC pool 1.

133. The portion of POM in the total suspended solids (Figure 17) and the composition of the POM (Figure 18) in Lower Cracraft Dike Field generally resembled those of the main channel during lotic sampling periods; the POM to suspended solids ratio was small, and detritus constituted the greatest portion of the total POM. A single exception to this was observed during the July sampling. This period was classified as lotic (Table 2) since a slight current was detected (5 cm/sec); however, river stage was falling (Figure 9) and both suspended solids and detrital POM were already well below corresponding main channel concentrations.

134. During lentic sampling periods, POM comprised a much greater portion of the total suspended solids than during lotic sampling periods (Figure 17), and detrital POM levels decreased and autochthonous POM levels increased (Figure 18). The suspended solids and POM composition tended to resemble that of Matthews Bend, although the autochthonous POM levels in the dike field never reached those of Matthews Bend.

135. The three dike fields sampled during the low water study period were all under lentic conditions. Lower Cracraft Dike Field contained the greatest area of water and was deepest; Leota Dike Field also covered a large surface area but was relatively shallow. The upper two pools of Chicot Landing Dike Field contained a small area and were generally shallow, except for a single deep pool. Significant differences in surface water quality conditions were detected between dike fields and between other habitat types (Table 4).

136. Greatest mean surface temperature among dike fields was found in Lower Cracraft Dike Field and lowest mean was found in the lentic portion of Chicot Landing Dike Field. Differences are attributed in part to meteorological differences. Samplings in Lower Cracraft and Leota Dike Fields were conducted on clear days; sampling in Chicot

Landing Dike Field was conducted on an overcast day. This would also in part explain differences in surface water pH and oxygen saturation between the lentic portion of Chicot Landing Dike Field and the other dike fields since photosynthetic activity is reduced on overcast days.

137. The bottom water temperatures in the deep plunge pools behind the first and second dikes of Lower Cracraft Dike Field and in the deep pool behind the second dike in Chicot Landing Dike Field were all in the 17.3° to 18.7° C range. These temperatures were at least 10° C below corresponding surface temperatures and approximately 12° C less than the main channel temperatures when river waters last flowed through these habitats.* Because these temperatures were within the 17° to 20° C temperature range of the alluvial groundwater aquifer near Greenville, Miss. (Taylor and Thomas 1971), and because they also had extremely high specific conductance values (over 900 μmhos/cm), these bottom waters probably represent groundwaters seeping into the pools. Assuming that this is the case, it is probably not unique to these few deep pools; in all likelihood, it probably occurs along many areas on either bank. However, only in a deep area or hole would these waters tend not to mix with other waters and thus maintain their groundwater characteristics.

138. Dike field surface waters sampled during the low water study period all contained significantly less total suspended solids than other habitats (Table 4); however, only Lower Cracraft Dike Field had significantly greater water clarity (as indicated by turbidity and Secchi disk transparency) than the main channel. This may be attributable to the relatively greater depth (paragraph 75) and area of this particular dike field.

139. Surface water values of specific conductance and concentrations of dissolved solids and total alkalinity during the low water study period were all greatest in the lentic portion of Chicot Landing Dike Field, followed by Matthews Bend (Table 4). Groundwater seepage probably contributed to the observed differences, showing a greater effect in smaller, shallower water bodies such as these two habitats.

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* Estimate derived from Figures 9 and 10.

140. Bottom water deoxygenation observed during the low water study period (paragraph 75) was proportionally greatest on an areal basis in deep, large Lower Cracraft Dike Field and least in the relatively shallow, large Leota Dike Field. Volumetrically, deoxygenated waters were proportionally greatest in the small but relatively deep lentic portion of Chicot Landing Dike Field, probably due to the fact that a single deep hole comprised a relatively large portion of the total volume.

141. Surface concentrations of nitrite-nitrate nitrogen and dissolved orthophosphate in lentic dike fields during the low water study period were all extremely low in comparison to the lotic habitats. All lentic surface samples were at or near the detection limit for dissolved orthophosphate. Habitat differences for mean surface water concentrations of ammonia and total phosphorus could not be clearly divided by habitat types (Table 4).

142. Day-to-day meteorological differences made it difficult to compare surface oxygen saturation and pH between habitats since these variables are affected by photosynthetic activity, which in turn is greatly affected by meteorological factors. Consequently, chlorophyll a is probably the best available variable to use when making across-habitat comparisons of photosynthetic potential. Lentic habitats naturally contained greater chlorophyll a concentrations than lotic habitats (Table 4). Matthews Bend contained greatest mean concentrations among all lentic habitats; the lentic portion of Chicot Landing Dike Field contained greatest mean chlorophyll a concentration among dike fields.

143. Differences between habitats were detected for DOM and POM (Table 4). Matthews Bend contained the greatest mean concentration of POM and the lentic portion of Chicot Landing Dike Field showed the greatest mean DOM. The composition of total suspended solids (Figure 19) was characteristically different between lentic and lotic habitats.

144. Water quality conditions in all dike fields would presumably be indistinguishable from those in the main channel and from each other during lotic periods. When flow through the dike fields ceases,

characteristic similiarity in water quality conditions between dike fields would start to decrease and the dike fields would become increasingly different from the main channel and from each other with increasing duration of isolation. The principal determinants of lentic water quality conditions within a dike field pool would probably be morphometric characteristics of the dike field. These include area, volume, mean depth, relative depth, shoreline length, etc. (Wetzel 1975). These morphometric parameters would affect water quality conditions through a number of mechanisms. For example, surface water currents would more easily resuspend bottom sediments in shallow pools than in deep pools and these sediments would be distributed within less water in the shallow pools resulting in higher suspended solids concentrations. Suspended solids concentrations, resulting from suspension of sediments by wave action along the shoreline, would be higher in pools with a relatively high ratio of shoreline perimeter to area. Shallow pools would tend to develop higher surface temperatures which would cause greater evaporation rates and could result in higher concentrations of dissolved solids. Pools with a relatively small volume or a relatively large shoreline development would tend to be more impacted by groundwater seepage. Shallow pools with a large area would tend to exhibit less stratification and proportionally less area of deoxygenated bottom waters than deeper pools.

Related Literature

145. Water chemistry data collected at main channel stations were generally within the range of values reported by the U. S. Geological Survey (1981) for routine water quality monitoring on the Lower Mississippi River at Vicksburg, Miss.

146. Bimonthly zooplankton samples were taken at Lower Mississippi River stations as part of the 5-year National Water Quality Network Study in which 125 stations from throughout all major waterways in the United States were sampled (Williams 1968). At Lower Mississippi River stations, rotifers were found to be the dominant zooplankton.

Keratella cochlearis was found to be the most abundant rotifer in the Lower Mississippi River samples and at stations in most other waterways. Rotifer densities varied inversely with suspended solids loading, tending to be greatest when turbidity was low and algal density high. In the present study (Table 8), major taxa encountered were in agreement with those found by Williams. Under strictly lotic conditions, zooplankton density did not show any significant correlation with either suspended solids, turbidity, or chlorophyll a, although significant correlations in agreement with those noted by Williams (1968) were observed when correlating all surface samples.

147. No other published environmental studies examining water quality conditions in aquatic habitats on the Lower Mississippi River were found. However, studies in other large river systems were found. In a study of the impounded Upper Mississippi River, Galtsoff (1924) observed that backwater areas and impoundments had denser plankton populations than the flowing water portions of the main channel. Platner (1946) conducted a more comprehensive limnological survey on the same system and observed great chemical variability between locations, sampling dates, and time of day. Most variables showed some correlation with discharge. Pulses of high discharge originating in different tributaries were apt to have different chemical characteristics. Backwater areas were increasingly different from the main channel as the degree of mixing between the two decreased, and the amount of time the waters had been in a lentic state increased. Platner (1946) concluded that, with the exception of localized zones of pollution, the system was generally suitable for aquatic life.

148. Although these two studies were conducted much farther upstream than the present study and in an impounded reach of the river, the findings were generally similar. Under lentic conditions associated with natural backwaters, impoundments, or dike fields, riverine waters undergo a rapid change in water quality conditions and become plankton rich.

149. In another study on the Upper Mississippi River, Dorris, Copeland, and Lauer (1963) compared physical-chemical limnological

characteristics of a flowing water chute with the main channel in Navigation Pool 21. They observed that, except during maximum spring discharge, the chute was always warmer than the main channel. Differences between the chute and the main channel for most chemical variables were slight during most flow conditions. Chute waters were almost always more turbid than main channel water; this was attributed to the presence of colloidal soil particles. During extreme low flow in the summer, the chute showed higher primary productivity than the main channel and was occasionally stratified. These findings were generally similar to those of the present study with the exception that relatively high photosynthetic activity was never observed in a secondary channel in the present study. This difference is attributed to current velocity differences between the areas studied. Secondary channel current velocities, observed in the present study, were approximately four times as great as those in the chute studied by Dorris, Copeland, and Lauer (1963).

150. Berner (1951) studied the limnology and ecology of the extremely turbid and highly modified Missouri River. Modifications consisted of channelization, use of extensive revetments, and placement of permeable pile dikes. Except for two short-lived, monospecific phytoplankton blooms, plankton density was extremely low. Suspended solids were observed to rise with flow, and an inverse relationship between dissolved oxygen and suspended solids suggested that an oxygen demand was associated with suspended solids. Berner concluded that the Missouri River is an allochthonous system, depending on input of terrestrial organic matter to drive the river's food chain. In the present study, chlorophyll a exhibited a pattern similar to that observed for phytoplankton in Berner's study. No significant correlation, however, was observed between dissolved oxygen and suspended solids; in fact, under lotic conditions percent oxygen saturation tended to increase with lower temperatures (Figure 21) which coincided with high suspended solids concentrations. The high level of detrital POM found in the main channel habitat in the present study tends to support Berner's findings that allochthonous organic matter is the principal source of organic matter in the river.

151. Morris et al. (1968) conducted a limnological study of several reaches of the Missouri River subjected to varying degrees of channelization. The channelized portions were devoid of chute, sloughs, and pools with the exception of the partial pools created by pile dikes. More diverse water quality conditions were found in the unchannelized portions which also yielded the greatest diversity and density of drifting organisms. In the Missouri River the reduction of physical diversity, principally flow, caused by channelization resulted in less diverse water quality conditions. Low physical diversity had a similar effect on water quality conditions in the present study. However, dike fields, which do act to channelize the main channel, acted to increase physical diversity by creating transient lentic habitats which have water quality conditions quite different from those of the main or secondary channels.

152. Several concurrent studies on the Upper Ohio River, just downstream of the confluence of the Allegheny and Monongahela Rivers, examined physical/chemical conditions (Woods 1965a), phytoplankton populations (Hartman 1965), and photosynthetic activity (Woods 1965b). Woods (1965a) found uniform physical and chemical conditions during high flow periods, and more spatially variable conditions as flow decreased. Hartman (1965) noted that phytoplankton developed in navigation impoundments during most times except during high flow; during low flow conditions, phytoplankton density was greatest as was station-to-station variability. Pulses of high flow acted to flush phytoplankton from the system. Woods (1965b) noted low productivity in winter and spring; primary production never appeared to be nutrient limited as flow appeared to be the principal limiting factor. In spite of regional and physical differences between river systems, the river-run navigation impoundments on the Upper Ohio River had effects on water quality similar to those of the dike fields examined in the present study. During high flow periods, spatial variability was negligible; as flow through the dike field decreased, spatial variability increased and primary production became increasingly important.

153. In an attempt to retard sediment accretion behind dikes and to create riverine access to closed ponds behind dikes and revetments on

the Missouri River, the CE began notching dikes and revetments. Jennings (1979) studied the aquatic habitats created by eight notched dikes of various configurations to determine their suitability as fish habitats. Two particular dikes created lentic "enclosed pool" environments specifically as a result of the placement of the notches. These pool habitats tended to be less turbid and warmer, and have greater primary productivity and plankton diversity than the other habitats studied. Jennings (1979) concluded that these pools were the most suitable fish habitats. These findings are in close agreement with those of the present study; appreciable water quality changes and photosynthetic activity do not occur when there are detectable currents within a dike field.

154. The related studies cited here would indicate that the findings of the present study are not unique and may have wide geographic applicability. The lotic environment within a given river reach on a given river system is fairly uniform; suspended loading is relatively high, water clarity is low, nutrient concentrations are not limiting, and algal density is low. When these riverine waters are exposed to lentic conditions, in natural backwaters, behind impoundments or in dike fields, water clarity increases and photosynthetic activity occurs resulting in further water quality changes.

Riverine Habitat Sampling Techniques

155. In the present study, few assumptions were made concerning the environmental functioning of dike fields; therefore, a general survey type sampling design was selected to characterize the habitats. Based on observations made during this study and the findings of this study, techniques for improved sampling designs are discussed for future studies with similar objectives.

Variable selection

156. Ideally, the variables selected in any environmental water quality study should be:

- *a*. Sensitive to the primary physical variables which distinguish the habitats under study.

b. Of ecological significance.

c. Reliably estimable.

d. Logistically easy to sample and handle, if possible.

157. In this study current was the primary physical variable which distinguished habitats. Physical variables associated with meteorological conditions were essentially the same among all habitats; other physical variables, such as light penetration and suspended solids loadings, were for the most part regulated by current velocity. Variables which showed a high sensitivity (showed high correlation with) to current velocity were (Figure 20): temperature, suspended soilds, Secchi disk transparency, turbidity, dissolved solids, specific conductance, total alkalinity, pH, oxygen saturation, nitrite-nitrate nitrogen, dissolved orthophosphate, chlorophyll *a*, zooplankton density, and POM. Although these variables were highly correlated with current velocity, it is doubtful whether any of the chemical or biological variables could be predicted from current velocity alone since the state of any variable is determined by a highly complex set of interactions. Certain variables showed no correlation with current velocity and showed no consistent pattern of difference between habitats, adding little to the characterization and comparison of habitats. These included: free CO_2, ammonia, total phosphorus, and DOM.

158. Ecologically significant variables are simply those which are important to or indicative of aquatic life. Those considered to be ecologically significant in this study are listed in paragraph 8. Not all of these were found to be sensitive to current velocity.

159. Reliability in estimating a variable will vary from study to study depending on water body sampled, handling techniques, analytic techniques, etc. Reliability estimates in this study were only made for variables requiring laboratory analysis (Appendix A). Greatest precision was observed for total alkalinity, nitrite-nitrate nitrogen, dissolved orthophosphate, and the gravimetrically analyzed variables including suspended and dissolved solids and their respective ash-free dry weights (POM and DOM). Some of the least precise variables were ammonia nitrogen, free CO_2, total phosphorus, and all photosynthetic pigments

except uncorrected chlorophyll *a*. Quite possibly, some of the variables which were not recommended for sampling because of insensitivity to current velocity only appeared insensitive due to the poor precision in estimating their values.

160. The last criterion is the logistical effort required to generate a data point. Some variables measure similar characteristics, and sampling all variables may produce unnecessary redundancy in the data set. An example would be surface water clarity which is estimated by turbidity and Secchi disk transparency. Between the two, Secchi disk transparency is logistically easier to collect than turbidity since it requires less equipment and less time to measure than turbidity. A well-designed field study using only in situ measurements can frequently generate as much useful information as a more cumbersome study with a large list of variables which require laboratory analysis.

Sampling time frame and design

161. Dike field water quality conditions were indistinguishable from those of the main channel when dikes are inundated. Information gained by sampling dike fields during these periods was negligible. During periods of no detectable current, suspended solids concentrations decrease, primary production occurs, and the dike field waters are more influenced by groundwater input. It is during these periods that careful study is warranted. The frequency and duration of lentic conditions during various times of the year should be used as criteria for selecting sampling times. The probable frequency and duration of lentic conditions during any time frame can be determined based upon dike elevation and from analysis of several years of river stage data, readily available for most navigable rivers. Priority should be given to sampling those periods with high frequency and duration of lentic conditions. Once a general sampling time period has been selected, sampling should be based upon actual river stage. Sampling should commence during a falling river stage, just before the flow over the dike has ceased. Immediately after isolation, samplings should be most frequent, then at increasing time intervals until de-isolation occurs. Changes in water quality conditions over the duration of isolation should be recorded for

the various times of the year. Ultimately, typical seasonal curves of water quality changes over time during isolation could be developed.

162. Photosynthetic activity in an aquatic environment results in diel variations in dissolved oxygen, pH, and several other variables. The magnitude of these diel variations is an ecologically meaningful variable. No such measurements were made in the present study; however, it is recommended that these measures be made in similar future studies. The consequence of completely ignoring diel fluctuation can be to detect significant differences between habitats, sampled sequentially over the course of a day, when the differences are actually attributable to time-of-day differences. To detect and account for possible diel fluctuations within the sampling design of a habitat comparison study, diel fluctuations should be determined within each habitat prior to collection of actual comparative data. To accomplish this with a minimum level of effort, dawn and late-afternoon profiles for temperature, dissolved oxygen, and pH should be taken at a single "representative" station within each habitat.* Habitats which exhibit negligible fluctuations can be sampled at any time of day. Habitats which exhibit appreciable fluctuations need to be sampled within some narrow window of time to minimize time-related variation. These time windows should preferably be either at dawn (for minimum dissolved oxygen concentrations), during the late afternoon (for maximum dissolved oxygen concentrations), or both.

163. In this study great horizontal and vertical homogeneity was found to exist in lotic habitats sampled at close points in time. No vertical water quality differences were ever detected at current speeds greater than 20 cm/sec. Extensive spatial sampling in lotic habitats is unnecessary; efforts should instead be placed on extensive spatial sampling in lentic habitats.

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* A better plan, if logistics allow, would be to take profiles at several randomly selected stations within each habitat at an interval of 3 to 6 hr. With these data, the shape of the diel curve could be approximated and a window of time for sampling could be selected in which temporal variation is minimal. Additionally, spatial variability could be estimated, and the number of stations sampled within each habitat could be apportioned based upon this estimate.

164. In lentic habitats day-to-day meteorological variations can be expected to have appreciable effects on water temperature, stratification, and photosynthetic activity which affects dissolved oxygen, pH, and several other variables. Comparisons between lentic habitats sampled on different days may lead to spurious conclusions. Ideally, habitats which are to be compared should be sampled simultaneously. If this is not possible, randomly selected stations in each habitat could be repeatedly sampled over the course of a few days at randomly selected times. While this sampling design would result in some loss of power in the habitat comparison, it would at least remain unbiased.

165. Platner (1946) noted that flowing waters in a large river system such as the Mississippi consist of a continual series of parcels of water of differing water quality from different areas of the watershed. This was most apparent during the low water study period when several habitats were compared. All lotic habitats except the main channel were sampled over short periods of time, usually less than 3 hr. Sample-to-sample water quality variations within these habitats were very low, probably indicating that a single parcel of water was sampled. The main channel, on the other hand, was sampled over the course of the entire low water study period, 7 days; sample-to-sample water quality variations were much larger than in the other lotic habitats, probably indicating that several parcels of water were sampled. Significant differences between the main channel and the other lotic habitats, and between each of the two other lotic habitats, were detected for several water quality variables (Table 4). It is suspected that these differences reflect sampling different parcels of water, not actual differences between habitats. To eliminate this possible bias, comparison of lotic habitats should be based on samples simultaneously taken in the various habitats. If this is logistically impossible, a series of main channel samples could be taken concurrent with a single lotic sample habitat being sampled. Comparison between lotic habitats other than main channel could then be made by referencing them to the main channel at the time of sampling.

PART VI: CONCLUSIONS AND RECOMMENDATIONS

Conclusions

166. The main channel habitat represented a physically severe environment with swift currents and high suspended solids loading. Water clarity was low; consequently, the photic zone was very shallow. Oxygen saturation and pH showed minimal seasonal variation; pH was slightly alkaline and dissolved oxygen showed a slight saturation deficit. Algal macro-nutrients were always abundant. Chlorophyll a and zooplankton densities were comparatively low for most samplings. A single pulse in the concentration of chlorophyll a was observed in the main channel in August accompanied by a slightly supersaturated level of dissolved oxygen. POM consistently comprised only a small portion of the total suspended solid and was composed almost entirely of detritus, except in August. The main channel habitat exhibited the lowest indications of autotrophic activity.

167. The abandoned channel habitat studied was continuously in a lentic state except during spring flooding. This habitat was consistently warmer than the main channel and had relatively high water clarity and low suspended solids. Total dissolved solids, specific conductance, and frequently total alkalinity in part were much greater than in the main channel. These water quality differences were probably the result of local surface and groundwater inputs. Nutrient concentrations were frequently near or below the detection level. Oxygen saturation and pH levels showed wide fluctuations due largely to high photosynthetic activity in this habitat. Chlorophyll a concentrations and zooplankton densities were far greater than all other habitats. The POM comprised an appreciable portion of the total suspended solids and was composed of autochthonous organic matter to a greater degree than in other habitats. This habitat showed greater signs of autotrophic activity than all other habitats.

168. The secondary channel habitats showed no appreciable deviation from the water quality conditions observed in the main channel.

169. Water quality conditions in the dike field habitats were indistinguishable from those of the main channel when dikes were inundated. Only in the complete absence of detectable current were water quality conditions appreciably different from those of the main channel. As flow ceased, suspended solids settled and water clarity and temperature increased followed by increased photosynthetic activity. Concentrations of dissolved substances were generally similar to the main channel as were nutrient concentrations at initial isolation. During lentic periods, chlorophyll a concentrations and zooplankton densities increased relative to those of the main channel but rarely approached those of the abandoned channel habitat. With alkalinity approximately equal to that of the main channel, photosynthetic activity in pooled dike fields resulted in far greater pH rises than those observed in the more productive but better buffered abandoned channel habitat. Suspended solids and POM composition shifted back and forth between characteristic lotic and lentic composition as water intermittently flowed through the dike field. During long periods of isolation from the river, dike fields became increasingly different, eventually developing their own water quality identity. Groundwater seepage and morphometric characteristics probably acted to determine ultimate water quality characteristics. Water quality conditions observed in dike fields during isolation appeared to be well suited for aquatic life with the exception of some anoxic bottom conditions.

170. The presence of a dike field created a transient lentic habitat with water quality conditions fluctuating between those characteristic of lotic and lentic environments. During lentic periods within a dike field, suspended solids and detrital POM dropped from the water. Autochthonous production subsequently occurred adding labile POM to the water column. As the river fell and rose, dike field pools isolated and produced autochthonous particulate organic matter which was subsequently released to the river as the habitat reflooded. This process may be beneficial to the overall riverine ecosystem since labile autochthonous POM was in relatively short supply within the main channel.

Recommendations

171. Effective water quality sampling of habitats within a large river system requires several special considerations: river stage, frequency and duration of river stage below flow-cessation stages of habitats under study, diurnal water quality fluctuations in lentic habitats, meteorological factors, and the changing characteristics of the flowing waters. The following recommendations are made:

a. Variable selection should be based on:

   (1) Sensitivity or anticipated sensitivity of candidate variables to physical variables which act to distinguish the habitats under study.

   (2) Environmental relevance of data set.

   (3) Ability to reliably measure the variable.

   (4) Logistical simplicity of collection and analysis.

b. Major sampling emphasis should be during low flow periods and should concentrate on lentic habitats.

c. Diurnal water quality variations within each habitat should be defined prior to major sampling. Timing of sampling should be based on this predetermined diurnal cycle.

d. Simultaneous sampling should be performed to make a valid comparison of different habitats. If this is not possible, repeated samplings in each habitat should be made over the same period of several days to a week.

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Table 1

Summary of Sampling and Analytical Procedures

Variable	When Sampled*	When Measured	Sampling and Handling Procedure	Preservative	Analytic/Calibration Procedure	Reference
Dissolved oxygen, mg/ℓ	M, L	In situ	Hydrolab surveyor 6-D, instrument precision = ±0.02		Daily calibration against Winkler	
Temperature, °C			Hydrolab surveyor 6-D, instrument precision = ±0.02		Daily internal calibration	
pH, S.U.			Hydrolab surveyor 6-D, instrument precision = ±0.1		Daily calibration against pH 7 and 9 buffets	
Oxidation-reduction potential, mV			Hydrolab surveyor 6-D		Daily calibration against ferric ammonium sulfate standard. Referenced to hydrogen standard	Light (1972)
Specific conductance, μmhos/cm			Daily Calibration against 0.05 M KCl ±10			

(Continued)

Note: USEPA = U. S. Environmental Protection Agency.
APHA = American Public Health Association.
* M = monthly study, all stations; *m* = *monthly study*, at MC-3, ACB-5, and DFC pool 1 only; L = low water study.

(Sheet 1 of 4)

Table 1 (Continued)

Variable	When Sampled	When Measured	Sampling and Handling Procedure	Preservative	Analytic/Calibration Procedure	Reference
Current speed, cm/sec	M	In situ	Endeco type 110 current meter		Calibrated annually	
Secchi disk transparency, cm	M, L	In situ	Standard 20-cm-diam limnological Secchi disk			
Turbidity, Nephelometric turbidity units (NTU)	↓	Laboratory	Sample placed in 4-ℓ plastic container	Stored on ice in dark	Measured with HOCH 2100A turbidimeter, calibrated daily	
Suspended solids, mg/ℓ	↓	↓	Sample placed in 4-ℓ plastic container	↓	Gravimetric analysis of material retained on GF/C filter after 104° C drying	USEPA (1979) (method 160/2)
Dissolved solids, mg/ℓ	↓	↓	Sample placed in 4-ℓ plastic container	↓	Gravimetric analysis of material passed through GF/C filter after 104° C drying	APHA (1975) (method 208C)
Total alkalinity, mg/ℓ as $CaCO_3$	↓	↓	Sample over-flowed into glass-stoppered bottle	↓	Titrated with 0.02 N acid to pH 4.5	(method 403)
Phenolphthalein alkalinity, mg/ℓ as $CaCO_3$	↓	↓	Sample over-flowed into glass-stoppered bottle	↓	Titrated with 0.02 N acid to pH 8.3	(method 403)

(Continued)

(Sheet 2 of 4)

Table 1 (Continued)

Variable	When Sampled	When Measured	Sampling and Handling Procedure	Preservative	Analytic/Calibration Procedure	Reference
Free CO_2, mg/ℓ	M, L	Laboratory	Sample over-flowed into glass-stoppered bottle	Stored on ice in dark	Titrated with 0.0454 N Na_2CO_3 to phenolphthalein endpoint	APHA (1975) (method 407B)
NO_2+NO_3 nitrogen,** mg N/ℓ	↓	↓	Placed in acid-washed 1-ℓ plastic bottle	5 mℓ H_2SO_4 stored on ice in dark	Colorimetric, automated cadmium reduction	USEPA (1979) (method 353.2)
Ammonia nitrogen,** mg N/ℓ	↓	↓	Placed in acid-washed 1-ℓ plastic bottle	5 mℓ H_2SO_4 stored on ice in dark	Colorimetric, automated phenate	(method 350.1)
Total phosphorus,** mg P/ℓ	↓	↓	Placed in acid-washed 1-ℓ plastic bottle	5 mℓ H_2SO_4 stored on ice in dark	Hot acid digestion with block digester automated molybdate/antimony colorimetric determination	(method 365.4)
Dissolved orthophosphate,** mg P/ℓ	↓	↓	Sample placed in 250-mℓ acid-washed plastic bottle	40 mg $HgCl_2$/ℓ, stored on ice in dark	Preliminary filtration through acid-rinsed 0.45-μ membrane Automated molybdate/antimony colorimetric determination	(method 365.4)

(Continued)

** Detection limit = 0.01.

(Sheet 3 of 4)

Table 1 (Concluded)

Variable	When Sampled	When Measured	Sampling and Handling Procedure	Preservative	Analytic/Calibration Procedure	Reference
Photosynthetic pigments, mg/m^3	M, L	Laboratory	Sample placed in amber 500-mℓ plastic bottle	Stored on ice in dark	Filtered through GF/C disk, $MgCO_3$ suspension added, 90% acetone extraction followed by spectrophotometric analysis	Strickland and Parsons (1972)
Zooplankton $\#/m^3$ by taxa, biovolume	M	↓	See paragraphs 34 and 35 of text			
Particulate organic matter, mg/ℓ	M, L	↓	Whole water sample placed in 4-ℓ plastic bottle	Stored on ice in dark	Loss on ignition of suspended solids exposed to 475° C for 2 hr	
Dissolved organic matter, mg/ℓ	M, L	↓	Whole water sample placed in 4-ℓ plastic bottle	Stored on ice in dark	Loss on ignition of dissolved solids exposed to 475° C for 2 hr	

(Sheet 4 of 4)

Table 2

Current Conditions at Time of Monthly Sampling

Sampling Date	Lower Cracraft Dike Field: Pool 1	Lower Cracraft Dike Field: Pool 3	Kentucky Bend Chute	Matthews Bend: ACB-5	Matthews Bend: ACB-8	Main Channel: MC-1	Main Channel: MC-3
	Station or Habitat*						
7 Nov 1979	L-15**	L-13	--	L-165	L-165	R	R(149)
20 Dec 1979	R	R	R	L-206	L-206	R	R(139)
17 Jan 1980	R(5)	R(113)	R(108)	L-234	L-234	R(118)	R(118)
27 Feb 1980	L-20	R(10)	R(108)	L-265	L-265	R(196)	R(196)
18 Mar 1980	R(82)	R(118)	R(113)	L-284	L-284	R(154)	R(242)
22 Apr 1980	R(98)	R(139)	R(144)	R(10)	R(10)	R(93)	R(139)
20 May 1980	L-3	L-1	L-1	L-20	L-20	R(144)	R(160)
19 Jun 1980	R(51)	R(39)	R(64)	L-50	L-50	R(116)	R(103)
23 Jul 1980	R(5)	R(5)	R(21)	L-84	L-84	R(196)	R(160)
15 Aug 1980	L-23	L-22	L-22	L-105	L-105	R(154)	R(144)
9 Sep 1980	L-6	L-4	L-4	L-130	L-130	R(129)	R(154)

* R = riverine state (current speed in cm/sec). L = lentic state (no detectable current).

** Numerals after L refer to approximate number of days in lentic state.

Table 3

Physical Water Quality Variables for Selected Stations

Sampled Monthly from November 1979 to September 1980

		Stations						
		Main Channel		Matthews Bend		Lower Cracraft Dike Field		Kentucky Bend Chute
Parameter	Statistic	MC-1	MC-3	ACB-5	ACB-8	Pool 1	Pool 3	TCK-A
Current speed, cm/sec	Mean (overall)	145	155	1	0.00	27	43	62
	(when detected)	145	155	10	--	48	71	93
	N	9	11	11	8	9	10	9
	Frequency detected (percent of samplings)	100	100	9	0	56	60	67
	Minimum	93	103	0	0	0	0	0
	Maximum	196	242	10	0	98	139	144
Suspended solids, mg/ℓ	Mean (overall)	90.3	117.2	22.0	39.2	76.5	55.3	73.4
	(lentic)	--	--	--	39.2	32.0	13.8	27.7
	(lotic)	90.3	117.2	--	--	106.2	88.5	96.3
	N	11	11	11	8	10	9	9
	Minimum	53.7	67.7	7.20	22.90	16.50	9.70	16.30
	Maximum	186.00	186.00	54.20	66.00	162.00	145.00	150.00

(Continued)

Table 3 (Concluded)

Parameter	Statistic	Stations						
		Main Channel		Matthews Bend		Lower Cracraft Dike Field		Kentucky Bend Chute
		MC-1	MC-3	ACB-5	ACB-8	Pool 1	Pool 3	TCK-A
Secchi disk depth, cm	Mean (overall)	22	23	55	48	30	43	30
	(lentic)	--	--	--	48	48	70	48
	(lotic)	22	23	--	--	21	25	19
	N	9	11	10	8	9	10	8
	Minimum	11	11	30	23	11	11	14
	Maximum	36	36	104	102	58	91	63
Turbidity, NTU	Mean (overall)	42	39	16	14	34	31	34
	(lentic)	--	--	15	14	14	9	13
	(lotic)	42	39	24	--	56	45	44
	N	10	10	10	8	9	10	9
	Minimum	23	10	6	7	10	7	10
	Maximum	63	64	52	34	66	62	61
Specific conductance μmhos/cm	Mean	422	417	506	556	421	433	422
	N	9	11	11	8	10	10	9
	Minimum	365	365	365	385	355	360	360
	Maximum	490	490	667	720	500	490	510

Table 4

Mean Surface Water Quality Variables by Habitat Collected During the Low Water Study Period, 10-17 September 1980*

Variable	Habitat						
	Main Channel	American Cutoff	Chicot Landing Dike Field (lotic)	Leota Dike Field	Lower Cracraft Dike Field	Chicot Landing Dike Field (lentic)	Matthews Bend
Temperature, °C	28.0bc	27.8bc	27.1c	29.0b	31.0a	26.9c	30.5a
Dissolved oxygen, mg/ℓ	6.7[cb]	6.1[cb]	6.3[cb]	9.1[b]	15.8[a]	6.9[cb]	13.7[a]
Percent oxygen saturation	84[bc]	79[c]	77[c]	118[b]	211[a]	85[bc]	180[a]
pH**	8.0[bc]	8.0[bc]	7.8[a]	8.2[cd]	8.7[e]	7.8[ab]	8.3[d]
Secchi disk depth, cm	25[c]	17[d]	17[d]	39[c]	55[a]	29[c]	38[b]
Turbidity, NTU	23[bc]	60[a]	60[a]	17[c]	7[d]	23[bc]	15[cd]
Chlorophyll a, mg/m^3	21.4[c]	15.7[c]	15.8[c]	68.2[b]	85.7[b]	130.6[a]	160.8[a]
Total alkalinity, mg/ℓ as $CaCO_3$	160[c]	125[c]	123[c]	159[c]	163[c]	365[a]	233[b]
Dissolved solids, mg/ℓ	286.0[cd]	273.3[cd]	292.5[c]	293.3[c]	263.9[d]	447.5[a]	371.0[b]
Specific conductance, μmhos/cm	473[cd]	460[cd]	465[cd]	496[bc]	453[d]	718[a]	532[b]
Suspended solids, mg/ℓ	80.3[b]	125.7[a]	155.4[a]	42.1[c]	23.7[c]	32.9[c]	53.3[bc]
POM, mg/ℓ	9.0[b]	9.3[b]	11.6[b]	12.1[b]	11.2[b]	11.7[b]	16.2[a]
DOM, mg/ℓ	47.1[c]	45.0[c]	62.9[b]	45.3[c]	41.9[c]	77.9[a]	51.8[bc]
NO_2 + NO_3, mg N/ℓ	1.270[a]	1.250[a]	1.130[a]	0.013[c]	0.220[b]	0.012[c]	0.120[bc]
NH_3, mg N/ℓ	0.048[ab]	0.047[ab]	0.010[b]	0.063[ab]	0.070[ab]	0.013[b]	0.125[a]
Total phosphorus, mg P/ℓ	0.23[ab]	0.27[a]	0.27[a]	0.18[bc]	0.11[d]	0.13[cd]	0.19[abc]
Dissolved orthophosphate, mg P/ℓ	0.083[a]	0.086[a]	0.082[a]	0.011[b]	0.011[b]	0.012[b]	0.014[b]

* Means followed by different letters are significantly ($P \leq 0.05$) different (Duncan's multiple range test).
** Analyzed as hydrogen ion concentration.

Table 5

Chemical Water Quality Variables for Selected Stations

Sampled Monthly from November 1979 to September 1980

Parameter	Statistic	Stations: Main Channel MC-1	Main Channel MC-3	Matthews Bend ACB-5	Matthews Bend ACB-8	Lower Cracraft Dike Field Pool 1	Lower Cracraft Dike Field Pool 3	Kentucky Bend Chute TCK-A
Dissolved solids, mg/ℓ	Mean	292.5	293.5	317.4	368.5	283.3	308.8	312.3
	N	11	11	11	8	10	10	8
	Minimum	233	220	250	260	230	242	239
	Maximum	546	532	376	462	403	552	576
Total alkalinity, mg/ℓ as $CaCO_3$	Mean	126.0	122.2	195.4	237.3	150.4	126.3	124.3
	N	10	10	11	8	9	9	9
	Minimum	102	97	97	96	96	95	96
	Maximum	150	146	320	346	350	174	168
pH*	Mean	7.8	7.8	7.9	7.9	7.9	7.8	7.8
	N	9	10	11	8	10	10	9
	Minimum	7.7	7.6	7.4	7.4	7.5	7.6	7.4
	Maximum	8.1	8.0	8.7	8.5	8.9	8.4	8.1

(Continued)

* Computed as hydrogen ion concentration.

Table 5 (Concluded)

Parameter	Statistic	Main Channel MC-1	Main Channel MC-3	Matthews Bend ACB-5	Matthews Bend ACB-8	Lower Cracraft Dike Field Pool 1	Lower Cracraft Dike Field Pool 3	Kentucky Bend Chute TCK-A
Free CO_2, mg/ℓ	Mean	3.3	3.9	1.6	3.6	2.8	3.5	3.2
	N	8	10	11	8	9	9	9
	Frequency detected (*percent*)	100	100	45	50	78	89	100
	Minimum	2.0	2.2	0	0	0	0	0.8
	Maximum	4.4	6.0	6.2	8.8	6.0	8.2	6.0
Dissolved oxygen *mg/ℓ*	Mean	8.7	9.1	12.7	11.0	10.5	9.4	9.0
	N	9	11	11	8	10	10	9
	Minimum	6.2	6.3	6.3	4.4	6.5	6.5	6.0
	Maximum	11.7	12.8	23.2	18.4	16.6	13.2	12.2
Dissolved oxygen percent saturation	*Mean* (overall)	88.4	89.0	143.3	125.7	102.7	96.6	92.2
	(lentic)					125.7	105.4	97.7
	(lotic)					87.4	90.7	89.4
	N	9	11	11	8	10	10	9
	Minimum	77.7	78.6	63.7	56.4	77.7	76.9	74.0
	Maximum	103.8	103.9	326.0	258.6	181.2	147.1	119.7

Table 6

Nutrient Concentrations for Selected Stations Sampled Monthly from November 1979 to September 1980

Parameter	Statistic	Stations: Main Channel MC-3	Stations: Matthews Bend ACB-5	Stations: Lower Cracraft Dike Field Pool 1
$NO_2 + NO_3$ mg N/ℓ	Mean	1.259	0.428	0.980
	N	11	11	9
	Frequency detected (percent)	100	73	89
	Minimum	0.764	0.010*	0.010*
	Maximum	2.060	1.340	2.030
NH_3, mg N/ℓ	Mean	0.290	0.237	0.249
	N	11	11	8
	Frequency detected (percent)	100	91	100
	Minimum	0.020	0.010*	0.040
	Maximum	1.340	0.620	1.070
Total phosphorus mg/ℓ	Mean	0.30	0.20	0.25
	N	11	11	9
	Frequency detected (percent)	91	73	89
	Minimum	0.10*	0.10*	0.10*
	Maximum	0.79	0.47	0.77
Dissolved orthophosphate mg P/ℓ	Mean	0.046	0.018	0.029
	N	11	11	9
	Frequency detected (percent)	100	36	78
	Minimum	0.013	0.010*	0.010*
	Maximum	0.080	0.040	0.080

* Detection limit.

Table 7

Biological Variables from Selected Stations Sampled Monthly, November 1979 to September 1980

		Stations						
		Main Channel		Matthews Bend		Lower Cracraft Dike Field		Kentucky Bend Chute
Parameter	Statistic	MC-1	MC-3	ACB-5	ACB-8	Pool 1	Pool 3	TCK-A
Chlorophyll a mg/m^3	Mean	18.8	15.3	42.4	66.4	24.5	17.1	19.1
	N	9	11	11	8	10	10	9
	Minimum	4.9	6.1	9.9	8.3	5.6	8.0	7.4
	Maximum	69.7	55.2	142.7	126.6	52.1	61.9	60.7
Zooplankton* $\#/m^3$	Mean	2.79×10^5	1.94×10^5	1.34×10^6	1.31×10^6	3.26×10^5	6.92×10^5	2.86×10^5
	N	9	9	9	8	7	9	9
	Minimum	1.6×10^4	2.2×10^4	5.5×10^5	6.8×10^4	5.7×10^4	7.4×10^4	2.9×10^4
	Maximum	8.9×10^5	6.2×10^5	3.08×10^6	5.1×10^6	6.8×10^5	2.8×10^6	9.8×10^5
DOM, mg/ℓ	Mean	51.8	58.1	47.3	58.6	51.0	59.1	54.7
	N	11	10	11	8	10	10	9
	Minimum	20.0	36.0	27.6	36.0	25.3	36.6	32.0
	Maximum	118.0	114.0	71.3	85.4	76.2	115.0	104.0
POM, mg/ℓ	Mean	8.1	9.2	8.4	9.4	9.6	8.4	8.3
	N	11	10	11	8	10	10	9
	Mininum	4.5	6.1	1.4	4.8	3.3	3.3	3.1
	Maximum	14.8	16.5	18.6	14.9	17.3	16.7	16.0

* Zooplankton sampling began in January 1980.

Table 8

Dominant Zooplankton Taxa Encountered in Monthly Study,

January to September 1980

Taxa	Percentage of Total						
	Main Channel		Matthews Bend		Lower Cracraft Dike Field		Kentucky Bend Chute
	MC- 1	MC-3	ACB-5	ACB-8	Pool 1	Pool 3	TCK-A
Rotifers	(79.3)	(81.7)	(90.5)	(87.2)	(73.6)	(84.2)	(84.1)
Keratella	(36.6)	(37.8)	(8.1)	(3.0)	(24.8)	(25.1)	(23.1)
K. cochlearis	33.0	33.6	7.9	3.7	24.4	24.5	22.0
K. quadrata	3.5	3.8	0.2	0.1	0.4	0.1	0.8
Brachionus	(9.6)	(10.9)	(25.8)	(30.4)	(8.2)	(17.8)	(19.3)
B. calciflorus	5.8	5.7	6.2	10.3	3.9	4.4	8.8
B. budapestinensis	1.1	1.6	0.7	1.2	2.2	3.7	1.7
B. angularis	1.3	1.8	10.3	9.6	0.7	7.0	4.6
B. caudata	0.9	1.2	7.9	8.2	0.6	1.6	3.9
Polyarthra	5.6	3.4	11.8	8.9	8.5	10.2	6.7
Hexarthra	0.3	0.2	2.3	0.3	0.1	1.2	1.8
Synchaeta	0.4	0.1	3.7	1.3	2.4	0.8	0.9
Trichocerca	0.2	0.5	5.8	1.8	1.3	4.0	1.1
Ascomorpha	0.0	0.6	0.8	0.2	0.1	1.7	1.8
Gastropus	0.3	0.4	0.3	0.1	0.2	0.1	1.7
Asplanchna	0.1	0.0	1.1	0.9	0.1	1.3	0.6
Filinia	0.3	0.3	1.4	0.5	0.5	0.7	0.8
Monostyla	0.1	0.0	0.0	3.1	0.0	0.0	0.0
Pompholyx	0.0	0.0	0.6	1.5	0.0	0.0	0.4
Unidentified rotifers	7.6	7.3	5.5	7.2	4.9	4.3	4.6
Rotifer eggs	16.1	13.3	22.8	27.2	22.1	15.5	19.3

(Continued)

Note: Percentages reported as 0.0 are less than 0.05 percent.

Table 8 (Concluded)

	Percentage of Total						
	Main Channel		Matthews Bend		Lower Cracraft Dike Field		Kentucky Bend Chute
Taxa	MC- 1	MC-3	ACB-5	ACB-8	Pool 1	Pool 3	TCK-A
Protozoans	(12.2)	(10.2)	(6.1)	(4.8)	(11.6)	(5.4)	(6.8)
Codonella	1.2	2.1	1.8	3.7	4.3	2.1	1.0
Vorticella	9.8	7.4	1.0	0.3	7.2	3.0	5.3
Unidentified ciliate	1.2	0.7	3.3	0.8	0.1	0.3	0.5
Copepods	(7.8)	(7.5)	(3.1)	(6.7)	(10.1)	(10.0)	(7.8)
Nauplii	7.3	6.9	2.6	6.5	5.9	9.3	7.2
Cyclopoid adult	0.5	0.5	0.5	0.2	4.1	0.7	0.6
Cladocerans	(0.6)	(0.3)	(0.3)	(1.0)	(4.5)	(0.3)	(1.2)
Ephippium	0.0	0.0	0.2	0.5	3.4	0.0	0.0
Diaphanosoma	0.1	0.0	0.0	0.3	0.2	0.1	1.1
Mean total density #/m^3	2.79 v 10^5	1.94 v 10^5	1.31 v 10^6	1.31 v 10^6	3.26 v 10^5	6.92 v 10^5	2.86 v 10^5

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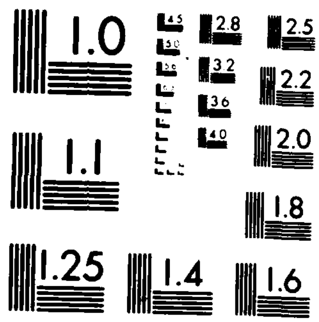

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APPENDIX A: QUALITY CONTROL PROCEDURES AND RESULTS

1. To quantify the precision of the water quality variables requiring laboratory analysis, two procedures were routinely conducted. First, during the monthly study, triplicate surface samples were collected at one or more stations during each sampling trip. Samples were labeled with a laboratory identification number and analyzed independently upon return to the laboratory. The coefficient of variation was computed for each set of triplicates. This procedure was intended to quantify variability associated with sample collection, handling, storage, and analysis. Second, in the laboratory, randomly picked samples were analyzed in duplicate. For each set of duplicates the range of the duplicates was divided by their mean and expressed as a percentage, giving a measure of variability. This procedure was intended to quantify variability associated with analysis alone.

2. These respective statistics are summarized in Table A1. Only duplicates and triplicates in which all values are above the respective detection limits are included in this table. A relatively high mean coefficient of variation for the field triplicates would indicate relatively poor precision for a given variable. If the variability of the analytical duplicates is also high, this would indicate that the analytic procedure is probably the source of the variability. A low analytic variability for the same variable would indicate that the source of variation lies in the sample collection, handling, or storage steps.

3. The photosynthetic pigments generally showed a very poor level of precision. The low level of analytic precision would suggest that the analytic procedure is the source of the variability. Of the photosynthetic pigments, uncorrected chlorophyll a showed the greatest precision for both procedures. Because of this, and the fact that all groups of algae contain chlorophyll a, uncorrected chlorophyll a was the sole pigment used in this study to indicate phytoplankton density.

4. With the exception of ammonia nitrogen, total phosphorus, free CO_2, and phenolphthalein alkalinity, all other variables showed a generally acceptable level of precision. Poor precision for free CO_2,

phenolphthalein alkalinity, and ammonia nitrogen apparently resulted from variability introduced during sampling, handling, or storage, since the analytic precision was good. The relatively low precision of total phosphorus appeared to be largely attributable to analytic procedures.

Table A1

Summary of Results from Quality Assurance Procedures

Variable	Sampling and Analytical Precision: Number of Triplicates	Sampling and Analytical Precision: Mean Coefficient of Variation	Analytical Precision: Number of Duplicates	Analytical Precision: Mean Measure of Variation*
Suspended solids	4	12.0	4	11.6
Dissolved solids	4	3.5	5	7.4
Particulate organic matter	4	13.0	4	15.9
Dissolved organic matter	4	5.8	5	7.3
Turbidity	11	14.0	8	2.1
Total alkalinity	11	2.6	29	3.0
Phenolphthalein alkalinity	1	44.0	2	0.0
Free CO_2	8	45.0	33	10.1
Nitrite-nitrate nitrogen	6	4.9	5	3.5
Ammonia nitrogen	7	55.0	5	1.6
Total phosphorus	7	27.0	5	22.0
Dissolved orthophosphate	6	6.0	5	8.5
Trichromatic chlorophyll a	12	18.3	27	22.6
Trichromatic chlorophyll b	11	44.7	27	55.2
Trichromatic chlorophyll c	11	51.2	26	90.1
Carotenoids (green, blue-green)	12	47.5	24	49.8
Carotenoids (golden brown, brown)	12	47.5	24	49.8
Active chlorophyll a	12	31.6	25	38.0
Phaeophytin a	12	58.3	25	89.5

* (Range/mean) × 100.